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FPL 1961

Annual Report of the Forest Products Laboratory

Forest Service, U.S. Department of Agriculture

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FOREWORD

This is the first annual report published by the Forest Products Laboratory in its 51-year history.

For some time a growing need for such a periodic report has been apparent, both within and outside the Forest Service. The Laboratory's golden anniversary, observed in June 1960 with ceremonies that attracted scientists, educators, industrialists, and government leaders from all parts of the Nation and foreign lands, strongly emphasized this need. On that occasion, the advances made in 50 years had been noted, contrasts had been drawn between the conditions and research requirements of 1910 and those of 1960, and new research needs of coming years had been focused upon.

The year 1961 is the first full calendar year elapsing since that anniversary celebration. It is, therefore, a singularly appropriate time to make this first annual report on FPL programs and work to the American public, in order to keep all who are interested in the work of this Laboratory currently advised on progress since the memorable occasion of the golden anniversary.

As the oldest institution of its kind in the world, FPL serves an industrial complex that annually produces 35 billion or more board feet of lumber, 7 billion square feet of plywood, 3 billion square feet of insulation board, 2 billion square feet of hardboard, a quarter billion square feet of particle board, and 34 million tons of paper and paperboard. It also serves the consumers of these products by making possible more efficient utilization of the forest resource and better service life of wood products. The good health of this industrial complex is vital to the economy of the Nation, for it constitutes collectively the Nation's fifth largest industry.

The function of this report is to present general facts of research progress during 1961. Detailed accounts of the work done must, however, be reserved to technical publications, where full information is available. Those in need of detailed information are referred to such reports. A list of technical and scientific publications issued during 1961 is appended.

Edward G. Locke
Director

FPL 1961: Annual Report of the Forest Products Laboratory

Introduction

Ever since it was founded at Madison, Wis., in 1910 as the first venture of its kind in the world, the Forest Products Laboratory has been operated by the Forest Service, U.S. Department of Agriculture, in cooperation with the University of Wisconsin. The object of the founders was to set up a single Laboratory to replace a number of investigations then under way at locations scattered from coast to coast. Experience with these had led to the conclusion that more effective work could be done at much less cost of time, money, and manpower by a well-rounded staff concentrated at one location, and representing all of the scientific disciplines needed to solve complex problems of wood research.

Results have borne out the soundness of that conclusion. Today FPL is widely known as a central source of knowledge and information about wood with perhaps the broadest program of forest products research under way at any comparable institution in the world. It has become a focal point of basic research and a source of ideas for product development by industry.

Broadly, FPL functions in four major areas of utilization research. These are (1) solid wood products, (2) engineering and packaging, (3) pulp, paper, and chemical products, and (4) wood quality. In this report, results attained during 1961 are presented under each of these area headings. Within each area are groups of studies concerned with a given subject matter. Each year certain studies are completed and new ones begun. In 1961 a total of 63 were completed.

Significant new studies included one on nationwide microclimate effects on wood, paints, adhesives, and particle board at stations set up near Olympia, Wash., Fresno, Calif., and Saucier, Miss., as well as Madison; one aimed at establishing a theory for pre-

Main building of Forest Products Laboratory at Madison, Wisconsin.

dicting the behavior of flat plywood and sandwich panels under normal load; the use of radio-active isotopes for evaluating wood properties; entomological studies of powder-post beetles and behavioral characteristics of subterranean termites; interference of fire-retardant chemicals in wood with adhesive bonding; effects of wind sway on trees as an environmental factor influencing wood quality; possibilities of altering the crystalline structure of cellulose to enhance its chemical reactivity; and improvement of dimensional stability and stiffness of paper through use of expander rolls on the paper machine.

Two salient features of basic significance to future progress at FPL emerged during 1961. These were a healthy expansion and diversification of staff and substantial success in reorienting the research program in line with changing and expanding needs of the forest products industries and users. The two developments were in a sense complementary. Expansion and diversification of available skills and talents made it possible to adjust the program more rapidly and smoothly than could otherwise have been done. The staff expansion became possible only because the Congress recognized the need for fresh approaches in an enlarged forest products research program.

Even with this expansion and diversification of research, however, it has been found possible to continue some lines of cooperative research with the Department of Defense. Most of this work, which has been continued ever since World War II, has been in the fields of adhesives, structural sandwich materials, and packaging. During Fiscal Year 1962, about 15 percent of the total Laboratory program continues to be devoted to such research.

Research in cooperation with private industry is holding about constant. During Fiscal Year 1961, ending June 30, 1961, a total of 126 projects were accepted. The total for Fiscal Year 1962 is estimated at about 130, ranging in cost from less than $200 to $12,000. This research deals mainly with utilization problems confronting an individual, private firm, or industrial group. To be acceptable, however, it must promise a significant contribution to knowledge. It is beneficial to the overall research program by keeping staff members in constant close touch with industry developments and current problems.

Expansion and diversification of the permanent staff resulted in the employment of a total of 51 more people during 1961, bringing the aggregate number of employees from 383 on January 1 to 434 on December 31. Of the new personnel, 19 were in professional categories and 6 with Ph. D. degrees. Thus, while total employment increased 13 percent and total professional employment about as much, there was a 25 percent gain in the number of professionals at the Ph. D. level. The growing competence of the research staff and the need for highly specialized personnel in ever more diversified fields of investigation are alike reflected in these statistics.

Necessarily, a review of a year's work by an organization such as FPL, operated on a national scale in subject-matter fields involving so many sciences, technologies, and professions, must be selective. The following pages contain a summarization of the more significant developments of 1961 in all areas in which FPL was active. It is entirely possible — indeed virtually certain — that in future years work given little or no notice in this report will yield major results. The nature of research is such that this must frequently be the case. It is one of the lures of scientific research that keep men searching for they know not what, much as the explorer is ever drawn across seas, mountains, and the voids of space toward the beckoning unknown.

As 1961 drew to an end, an "electronic brain" was added to FPL's data processing equipment. Extensive use is expected to be made of the new computing unit, shown being operated by Statistician Wencil W. Wlodarczyk. Typical of its capabilities are 1,780 additions or subtractions or 200 multiplications of 5-digit numbers per second.

M101 194

Solid Wood Products Research

All processes and treatments by which wood is made serviceable, from the sawing of round logs to the utilization of sawdust and other processing residues — as well as processes, such as slicing, to eliminate residue — come within the scope of research on solid wood products. The reason is readily apparent; by making wood more completely serviceable, research in this area contributes to the conservation of our most valuable renewable resource, timber. The benefits of preservative treatment against decay and insects are a familiar example. Railroads and utilities have estimated that they save a million dollars a day because railroad ties and communication poles last much longer. Without such treatments, our forests would have to yield 7 billion board feet more of these products each year.

FPL research encompasses the many kinds of operations involved in the processing and protection of wood in its solid form. The production of lumber, veneer, plywood, laminated wood, and particle board; machining operations; preservative and fire-retardant treatments; painting and finishing; glues and gluing techniques; and seasoning operations comprise the principal processing investigations under study.

Supplementing these are basic studies that encompass fundamental cutting actions of saws, knives, and other tools; chemistry of preservatives, fire retardants, adhesives, and finishes; pyrolysis and related effects of heat and combustion; and the growth and life cycles of decay and staining fungi, bacteria, and insects that attack wood. New developments in all of these branches of research are covered in this section.

Environmental Research

Perhaps the most significant new development in timber processing research during 1961 was the launching of a new fundamental program aimed at studying, nationwide, the effects of climate on the service of wood products.

Exposure of new products to the weather and other actual service conditions to determine their serviceability is, of course, a widely known procedure used by FPL for many years. In the past, however, little or no attention has been paid to actual weather conditions beyond taking note of the nearest Weather Bureau data. In the new environmental research program, day-by-day weather conditions and effects at the site will be recorded and closely followed.

The program is so new in concept and execution that new instruments and procedures will have to be developed. Advice and cooperation of the University of Wisconsin meteorology department will be available in this phase of the program to develop the needed procedures for measuring such exposure variables as the temperature prevailing on the actual surface of exposed products at all times, the relative humidity of the adjacent air, and accumulation of water, snow, or ice on surfaces. Collectively these variables are known as microclimate, and may differ quite radically from conditions observed at the nearest Weather Bureau station.

Two exposure sites long used by the Laboratory at Madison and on the Harrison Experimental Forest maintained by the Southern Forest and Range Experiment Station near Saucier, Miss., have been supplemented with new sites near Olympia, Wash., and Fresno, Calif. The Washington site is operated in cooperation with that State's Department of Natural Resources. The California site is on the San Joaquin Experimental Range of the Pacific Southwest Forest and Range Experiment Station.

M 120 829

Mounting plywood specimens for studies of microclimate effects on San Joaquin Experimental Forest, central California.

Some products were put on exposure racks at all four sites during the fall and winter of 1961. Among them were wood house siding, plywood, laminated beams, and particle board. Glues, paints, and natural finishes were applied to some of each type of specimen and will be included in the observations of exposure effects.

As techniques and instrumentation are developed, studies will be pushed on the basic factors that affect materials exposed to weather; microclimate factors that affect product performance; types and rates of deterioration of wood products as related to environment; and short-term tests simulating long-term weathering.

The overall object of this work is to devise more durable and longer-lived wood products under the comprehensive range of conditions included in this nationwide program.

Seasoning Research

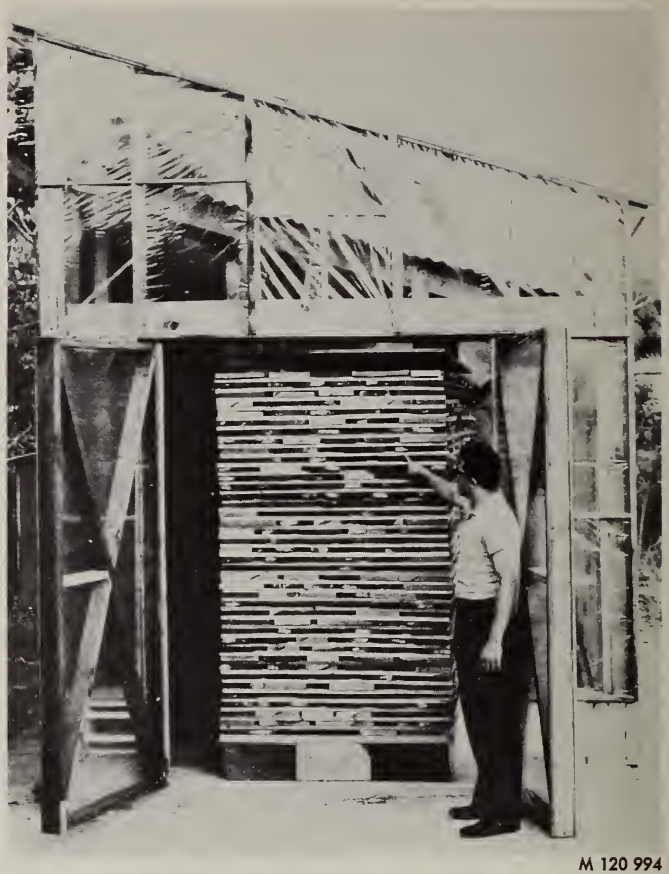
Spadework was done to prepare the foundations for a national seasoning research project that would include studies at various forest experiment stations designed to apply FPL research results to local conditions, as well as other studies sponsored at universities by the Forest Service.

A senior FPL seasoning specialist visited various parts of the United States to make studies necessary for the preparation of problem analyses on needed research in air seasoning, predrying or forced-air drying, kiln drying, and drying fundamentals. Proposals were discussed with research and teaching personnel at colleges and universities and with Station research group leaders. The project is conceived as a means of bringing the results of basic FPL research more directly to bear on regional and area problems of seasoning, with emphasis on local conditions and species.

Solar Dryers for Seasoning

A new simplified design for a solar-heated lumber dryer, the latest in a series of such designs experimentally developed during several years of research, proved especially effective in drying lumber. Two runs of red oak boards were dried to 20 percent moisture content in less time than a dryer of earlier design, and indications are that drying to 10 percent may be economically as well as technically feasible. Such complete drying would remove the dryer from the "predryer" category, for which it was originally conceived to dry hardwood lumber partially before it is kiln dried.

The earlier design had consisted of a black metal inner lining of walls and roof and an outer skin of a clear plastic film. In the new design the black metal lining is eliminated, and two sheets of film held 1⅝ inches apart by a wood frame to provide a heat trap comprise the wall covering. Detailed building plans were prepared.



M 120 994

In sun-bathed Puerto Rico, FPL solar dryer halved normal air-seasoning time of mahogany lumber.

From these plans a dryer was built with FPL assistance at the Institute of Tropical Forestry, Rio Piedras, P.R. The initial pilot run in this dryer began October 26 on 1¼-inch mahogany lumber at about 50 percent moisture content. After 19 days of drying, the lumber had gone down to 14 percent moisture content, and 6 days later it averaged 12 percent. Drying proceeded twice as fast as in an air-drying pile adjacent to the dryer. Since Puerto Rico lacks drying facilities, two concerns there immediately showed interest in the commercial possibilities of the solar dryer.

Hemlock Seasoning Program

A major target of FPL seasoning research during 1961 was to break a seasoning bottleneck that has largely blocked utilization of extensive stands of mature eastern hemlock in the Lake States. During the past decade, very little of this species has been cut because of ring shake and extreme variations in moisture content of green material. Estimates are that an annual cut of 15 million board feet is feasible

during the next few years without danger of overcutting. Considerable second growth more than 100 years old is available, along with old growth up to 500 years old.

A proposal for a high-speed stud mill at Newberry, Mich., by private interests with Government aid, triggered the FPL kiln drying experiments to break the seasoning bottleneck. Several Lake States mills contributed material or cooperative funds for the work.

The moisture content variability problem was solved by dividing the material received for experiments into three weight classes, light, medium, and heavy. Short-length samples in each class were experimentally dried to determine suitable kiln schedules. A preliminary steaming was found desirable in drying the heavy high-moisture content material in the same time to the same stage of dryness as the medium-weight stock.

Schedules decided upon for trial with full-size studs were mild enough so that ring shake existing in the standing timber would not be aggravated. At year's end work on this was continuing.

Chemical Seasoning, Stabilization

In two widely divergent fields — military weapons and museum specimens — the FPL process for seasoning and stabilizing green or water-soaked wood played a key role during 1961.

The unprecedented reliability of wood gunstocks chemically stabilized and seasoned by the fiber-bulking process was dramatically demonstrated by the U.S. Marine Corps Rifle Marksmanship Team.

Stocks furnished through an FPL cooperator were fitted to Marine rifles and field-tested at San Diego, Calif., Quantico, Va., and Camp Perry, Ohio, scene of the annual national rifle championships. Through drastic changes in climate, the rifles remained highly accurate in target competition while weapons fitted with untreated stocks had to be "zeroed in" and barrel-to-stock fittings adjusted repeatedly because accuracy was lessened by slight dimensional changes in the stocks with changing relative humidity.

Equally marked results in the reduction in potential seasoning time were achieved meanwhile with treated stocks. By "bulking" the fiber walls of wood, the chemical largely prevents shrinkage in drying. Green stocks shaped and inletted from freshly cut, treated walnut were kiln dried in 20 days as compared to the 120 days normally required in industry for drying of untreated walnut blanks. Seasoning degrade losses were negligible.

Marine officials obtained a substantial number of treated stocks from commercial producers to outfit the 1962 marksmanship team, and Army officials at Springfield, Mass., Armory are studying stabilized stocks for use on the new M14 automatic military rifle that is now approaching large-scale production.

Meanwhile, at Blue Mountain Lake, N.Y., officials of the Adirondack Museum were aided by an FPL specialist in applying the polyethylene glycol treatment to water-soaked wood of two colonial bateaux raised from Lake George. The 30-foot craft, of a type commonly used by lumbermen rafting logs downstream in Canada and the American colonies, were raised by skin divers. The wood, however, was so weak from centuries of water logging and decay that some of the pine planking broke. Worse, pieces crumbled when dried. This prompted the museum director to contact FPL for aid, and the chemical treatment was successfully put to use.

Coincidentally, from Stockholm, Sweden, came news that a seventeenth century Swedish man-o'-war,

Marine sights .300 magnum target rifle equipped with stock of FPL stabilized wood.

the Vasa, raised from that city's harbor after 330 years, would be treated with polyethylene glycol to preserve it. In 1960, a Swedish businessman had conferred at FPL on use of the process to preserve the unique wooden vessel. The ship was a treasure trove of craft and art objects of the period, many of wood.

Glue Chemicals from Bark

Experiments on bark from 10 species of trees uncovered bright prospects for obtaining chemicals that may yield useful wood glues. Sugar pine bark was found to have an especially high content of substances that react with formaldehyde or with phenol-formaldehyde resins to form promising adhesives. Work was begun to develop methods of isolating the reactive components from the bark, determine more fully their adhesive-forming ability, and find ways of preparing adhesives from them.

Gluing Building Components

A modest beginning was made on a new approach to solving a problem that has long beset builders — how to utilize glues more extensively in the assembly and erection of component parts. The approach was facilitated by discovery of a method of measuring strains in glue lines that excludes deformations in the wood itself. The technique consists of measuring microloads in a very small joint by means of a microscope or photographic enlargements. This made possible the first reliable determination of modulus of rigidity of adhesives. It was applied to a series of experimental adhesives based on epoxy-sulfide rubber combinations.

The technique led to a large-scale exploratory study of the performance of these adhesives in joints between wood parts at different angles of grain that were subjected to cyclic moisture content changes. Being sought is an adhesive of sufficiently low modulus of rigidity that it can deform to accommodate differences in shrinkage or swelling of two wood parts it holds together at 90° angles of grain in the joint. This investigation of stress-strain relationships in glue joints is being continued.

Finger Joints in Lumber

Socalled "finger" joints have long beckoned producers of lumber, millwork, and other wood products as affording a means of joining short pieces end to end into longer ones. Where strength is of minor importance, such joints are successfully used. In load-carrying members such as floor joists and roof rafters, however, finger joints are as a rule inadequate. Requirements for accurate cutting and fit also limit their utility.

An investigation was launched during 1961 into the geometry of finger joints — notably such factors as the length of the fingers, the slope of the face of the finger with the axis of the joint, the pitch of the fingers, and the thickness of the fingertips. The relative importance of these factors is being studied as a means of developing specific joint designs assuring the strength levels required for different uses. Less rigid types of adhesives are also being tried in such joints.

M 101 216

Gluing finger-jointed wood specimen for evaluation of joint design.

Gluing Chemically Treated Wood

Preservative chemicals of various kinds are well known to interfere with gluing. During 1961, the gluing of fire-retardant-treated wood was investigated on both a trouble-shooting and a more inclusive basis. For a commercial firm, stop-gap information was developed on a cooperative basis for one proprietary treatment that solved a problem met in gluing laminated members of southern yellow pine.

A more basic study was meanwhile begun to determine which chemicals used in fire retardants cause interference with the setting of the glue and to indicate, if possible, the nature of such interference. One aspect being investigated is the likelihood of chemical interference while the resin molecules are curing or polymerizing at the interface.

Particle Board

In 10 years, the particle board industry has rocketed to a production level rivaling that of the much older hardboard industry. Technological growing pains have inevitably developed because commercial growth has outdistanced research to establish the suitability of the product for various service conditions.

Some limited research on such major problems as particle geometry, resin content, and wax effects on board properties, and the effect of species and weathering was continued during 1961. Of special promise from the technological standpoint was development of a planer-matcher head that produces shavings, while planing lumber, that are more suitable than run-of-mill shavings for particle board. Particle board

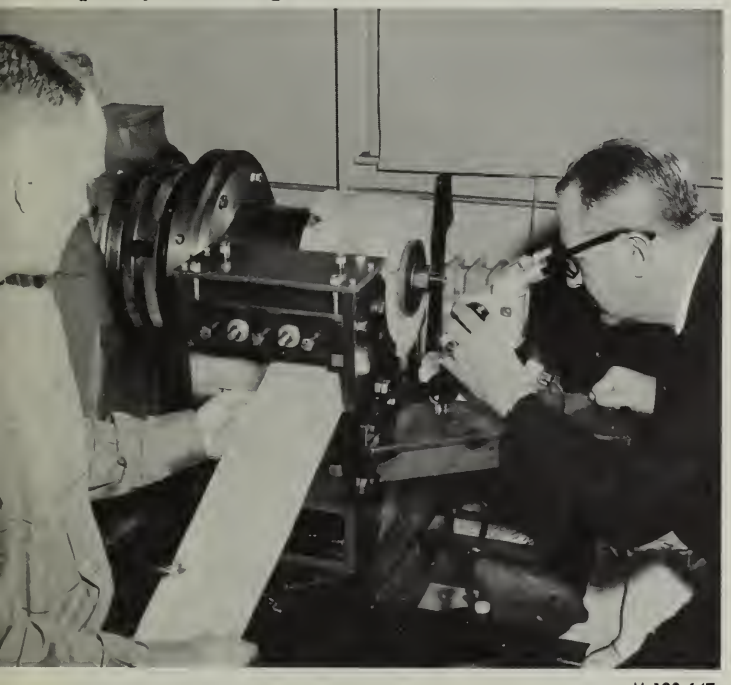
made from these shavings had superior strength properties.

Flakes from three species of wood differing in density but otherwise of similar growth characteristics were incorporated in particle boards ranging in density from 20 to 60 pounds per cubic foot. The species of lowest density produced the best boards.

Experimental particle boards made with various binders and Douglas-fir flakes withstood 3 years of outdoor exposure with results traceable to the binder used. Binders of phenolic resin, melamine-urea resin, or urea resin plus wax deteriorated only moderately, and mainly during the first year. Boards with urea resin alone as the binder, on the other hand, underwent almost complete deterioration.

Veneer Quality

Timber quality factors that govern the quality of veneer produced by rotary cutting are being analyzed with the object of establishing a firm basis for genetical and silvicultural methods of improving the quality of trees grown for veneer.



M 120 647

Director Edward G. Locke (right) watches miniature lathe knife cut through southern pine in rotary cutting experiment while Technologist John Lutz examines veneer.

Preliminary studies with new equipment designed to permit close observation of the wood as it is cut are shedding new light on how such defects as lathe checks, roughness, and shelling develop. For example, indications are that shelling is related to growth rate, orientation of the annual rings, and pressure exerted by the lathe's stationary nosebar. The importance of growth rate, ring orientation, and other growth and heredity characteristics can thus be evaluated in terms of veneer quality. The work is to continue for several years on various species. The present program involves only southern pine.

Slicewood

Two years ago a new term appeared in the lexicon of the forest products industries. "Slicewood" emerged as the name of a new FPL-born product fitting the definition of neither lumber nor veneer. Thicker than veneer as usually conceived, it was the product of a veneer slicer rather than the saw, hence not meeting the standard definition of lumber.

Nevertheless, this product attracted industry interest almost before it emerged from its laboratory cocoon. During 1961, research continued on requirements for its production, characteristics of the product, and machinery suitable for commercial production.

Since no sawdust is produced, at least 20 percent more usable material is obtained from the log by slicing than by sawing. Slicewood is nearly as high in bending strength as sawn lumber but significantly weaker in tension perpendicular to the grain because of knife checks that develop during slicing. It is somewhat more likely to split when nailed, but can be fastened with air-driven staples without splitting. Pieces are readily glued together for laminated products straight or curved.

Because heavy-duty slicers are necessary for commercial production at rates equivalent to those of sawmills, developmental work is being pushed on such a machine, utilizing experience gained with the veneer slicer heretofore used.

Sawmilling Better Lumber

Logs from young second-growth trees often yield lumber that warps excessively. The cause generally is laid to abnormal wood called compression wood and socalled "juvenile" wood found in the center of logs. Under investigation are methods of sawing logs 6 to 12 inches in diameter in order to increase the number of pieces of lumber free from warp-inducing wood.

Experiments are under way on the production of pulpable sawdust from oak. This is a follow-up on previous work done with southern pine, in which it was demonstrated that production of pulpable sawdust particles resulted in excessive loss of potential lumber; the value of the lumber lost was greater than that of the sawdust chips produced. The theory has been put forward, however, that with hardwoods, which have much shorter fibers than softwoods, smaller sawdust particles might make acceptable pulp, hence less drastic sawing procedures could be used.

M 101 161

F. B. Malcolm, small sawmill specialist, operates FPL's experimental sawrig in a kerf-chip sawing experiment.

Preliminary indications obtained by sawing oak boards are that oak chips break up more than southern pine chips and that saws tend to "snake" or deviate excessively at sawtooth bites greater than 3/16 inch. Roughness of oak boards was not acceptable from a planing standpoint at sawtooth bites greater than ¼ inch.

FPL sawmilling specialists, at the request of the International Cooperation Administration, conducted sawmill seminars in Mexico and inspected 20 million board feet of questioned lumber for grade in Korea. The lumber purchase had been financed by ICA for the Republic of Korea. Sawmill clinics were conducted in Oregon, Washington, and Michigan.

Wood Paints

The value of paper-plastic overlays for improving paint life on lumber and plywood has been demonstrated in outdoor exposure studies, some of which have continued for a decade. On overlaid plywood and flat-grained southern pine lumber, certain paints continue to perform amazingly well after 9 years. Little or no abnormal paint failure in the form of cracking and peeling is apparent. It appears clear that the overlay reduces or distributes concentrated stresses normally exerted on paint films by the shrinking and swelling of wood. Improved performance of paints and putty on window sash treated with water repellants confirms these observations.

Other exposure studies up to 6 years old are demonstrating that commercial emulsion-type paints for wood are superior in performance to the older oil-base paints. The improvement is ascribed to the fact that oil binders exposed to radiant energy undergo oxidative degradation, while the polymers in resin emulsians can be made to resist such degradation.

The promising results with overlaid plywood and lumber have prompted the launching of new basic studies of the elastic properties of emulsion polymers and the magnitude of swelling strains in wood surfaces as measured in microscale. Investigation is under way on techniques of polymerization, polymer characterization, and tests of physical and elastic properties of emulsion polymers. Simultaneously, work has begun on developing criteria on elastic requirements of films by micro-measurement of swelling strains that occur in wood surfaces because of variations in wood structural elements. As a result of these studies, it is expected that new paints may be formulated that are elastic enough to withstand stresses developed without breaking.

Improved Fire Safety

Long-range research is under way on various applied and fundamental approaches to the overall problem of improving the fire resistance and safety of wood structures. This work is proceeding in four general areas, (1) the fire endurance of wood struc-

M 101 212

Adjusting needle to measure and record surface irregularities of plywood with electronic equipment in wood-finishing experiments.

tures, (2) the surface ignition and flame-spread characteristics of wood, (3) fundamental studies of pyrolysis and combustion, and (4) treatments for improving fire resistance.

A small beginning has been made on the investigation of fire endurance of wood structures. Glued joints were demonstrably superior to bolted joints in wood trusses loaded while exposed to fire. Some exploratory charring rate tests have also been made.

An investigation of flame-spread characteristics of decorative and fire-retardant coatings on wood is nearing completion, and related flame propagation temperatures have been determined for different materials and correlated to the flame-spread index of the FPL 8-foot fire tunnel test.

Basic pyrolysis research under way for several years is currently aimed at defining the effects of certain fire-retardant salts on the basic physical and chemical reactions that take place during the pyrolysis of wood. From chemical knowledge thus developed, better ways of controlling and inhibiting pyrolysis and combustion in wood are expected to emerge.

Decays and Discolorations

Perhaps no limiting factor on wood use has been more generally misunderstood than the decay hazard. Generally speaking, the hazard is slight when wood is not in contact with the ground and can be largely eliminated by sensible precautions during construction and maintenance of wood structures. Among such precautions are structural methods that assure shedding of rain water so that it does not infiltrate and collect in joints; use of adequately seasoned lumber; protection of wood from contact with the soil; and use of toxic preservatives to prevent inroads of decay fungi where exposure is severe, as in posts, poles, piling, and fully exposed lumber.

Research into the nature and causes of decay has long since exploded the myth of "dry rot." Wood kept reasonably dry is well protected from decay-causing organisms, which need considerable moisture to survive.

Basic research on decay and its causes continues in such areas as the natural decay-resistance of different species, the identification and physiological characteristics of decay fungi, and conditions that cause decay to start and develop in wood, whether logs, stored lumber, poles, or in buildings and other structures.

Among species evaluated during 1961 for decay resistance of their heartwood were four Hawaiian woods, a Chilean species, and one of the Philippine "mahoganies," *Shorea guiso*.

Dry and moist heat normally encountered in commercial processing of wood have only slight effect on the decay resistance of eight highly durable woods, an extensive evaluation of heat effects disclosed. The high natural decay resistance of incense-cedar heartwood was concluded to be due to several phenolic-type extractives isolated in a toxicity study.

Research was continued on the socalled "soft rot" type of fungus, whose existence and major characteristics have been disclosed by FPL research in recent years. Microscopical study of how soft rot attacks wood revealed that it probably enters the cell wall through tiny holes hitherto unnoticed and leaves typical cavities in the secondary walls adjacent to these holes. Certain soft-rot fungi were found to have unusual capacity for developing in wood with little oxygen. Work on an accelarated test for determining the effectiveness of preservatives against them is proceeding.

A previously unidentified brick-red discoloration in the heartwood of lodgepole pine was found to be caused by the fungus *Corticium fuscostratum*.

In other studies, chemical stains in sugar maple, hackberry, black gum, tupelo gum, and sweetgum appeared in all cases to be due to the enzymatic oxidation of certain wood constituents upon exposure of the moist wood to air. Rapid drying or exposure of the wood to high temperatures has prevented or reduced the discolorations.

Substructures of houses are generally free from serious decay hazards, but exterior components exposed to rain probably should be more extensively treated with preservative at present, it was concluded on the basis of a 2-year survey of more than 1,000 houses for the Federal Housing Administration. More than 12,000 moisture-meter readings and decay observations were made in seven major home-building areas.

The deterioration of gum and oak pulpwood chips stored in piles was found to be due principally to the attack of soft-rot fungi. Decay by typical wood-rotting fungi, however, also was important, which is in contrast with earlier findings on stored pine chips. Deterioration of the stored chips was confined largely to the outer few feet of the piles, and was greater for gum than for oak chips.

Termite Biology and Control

Wood entomology is a comparatively new field of research at FPL. Significant results are already at hand, however, with the discovery of a termite attractant that is the product of certain decay fungi. Experiments demonstrated that the product consistently lures termites to wood containing it.

The department of entomology at the University of Wisconsin is exploring the chemical structure of the attractant. The behavior of termites toward the attractant is being studied by FPL entomologists with the object of ultimately coupling it with insecti-

M 120 488

Entomologist Glenn R. Esenther examines jar containing wood for evidence of termite attack in infested area. Only jars containing wood decayed by fungi that were subsequently killed attracted insects.

cides as a possible control measure. Two colonies of termites in Wisconsin are under close surveillance.

Preservative Chemicals, Processes

Investigations of wood-preserving chemicals and treating processes have long been major fields of FPL research. Many continuing experiments are now a quarter century old. Each year two reports on results are brought up to date, one on stakes treated with various preservatives and another on posts treated and exposed on the Harrison Experimental Forest in Mississippi. A running record is thus published annually on the effectiveness of a large number of preservatives new and old.

Many thousands of wood poles are used each year by telephone and electric power utilities. While these are usually preservative treated, decay eventually starts, especially at the critical groundline. For some years FPL has experimented with special groundline treatments of poles in place. Paste- or grease-type preservatives containing rather high concentrations of toxic chemicals have been the most effective yet tried for arresting surface decay but not for internal decay.

Freshly cut poles are often stored for long periods before being treated with preservative. Pretreatments to protect them from decay, mold, and stain have been developed in exploratory studies. Pilot trials of concentrated solutions of ammonium bifluoride or borax-boric acid have begun at a Louisiana wood-preserving plant on southern pine poles.

Means of improving the cleanliness and paintability of pressure-treated wood are under way with various solutions containing pentachlorophenol. A simple indicator test was developed for determining paintability of the treated product.

The oscillating pressure method (OPM), developed in Sweden for the treatment of refractory woods, did not improve treatment of the heartwood of a number of our native impervious woods. However, sapwood penetration of preservatives was improved in green material of several of the species tested.

Chemical analyses were completed for 12 Hawaiian species given a double diffusion treatment by the Pacific Southwest Station and installed in the Makika exposure site at Honolulu. Similar analyses were made of 29 Puerto Rican species treated by the Institute of Tropical Forestry and installed in Puerto Rico. Chemical analysis showed that a fair percentage of species at both installations hold considerable promise for effective treatment by the double-diffusion process.

Extensive data were obtained on the distribution of four preservatives in southern pine and Douglas-fir lumber treated by conventional pressure methods. The data will serve as a basis for developing an assay method for results-type specifications, as part of a quality control program to improve the performance of preservative-treated lumber.

Research on nontoxic treatments that impart decay resistance to wood, which have been developed by FPL in recent years, was continued, with emphasis on the destruction of minor nutrients in wood that are essential for fungi. Test material in which thiamine was destroyed was exposed above ground in the Harrison Experimental Forest near Saucier, Miss. Painted and unpainted material was included to determine the effect of paint on thiamine uptake from airborne contaminants.

A new project with the Navy Bureau of Yards and Docks is aimed at improving the treatment and maintenance of marine piling. Under development are simple analytical methods for use in quality control-type specifications for procuring new piling or for inspecting piling in service. Analyses of piling that had given both good and poor service continued to show that the type as well as the amount of preservative initially injected can be very important in piling performance. Comparisons of the triethylene glycol-furfural (TEG-F) and specific-gravity-of-fraction methods for detecting petroleum in creosote indicated that TEG-F was somewhat more sensitive.

Wood Products Engineering Research

Engineering research has been an important part of the FPL program throughout the Laboratory's existence. The reason is readily apparent: Probably the first question anyone asks about a structural material is, how strong is it?

The strength of wood as a structural material, the strength of other materials made of it, and the strength of structures built with these materials can be established only through research in terms needed by structural designers. Thus it is that, although wood has been used for thousands of years to build many kinds of structures, it has become a modern engineering material only since research established the data and criteria needed for design purposes. The results of this research are widely applied in homes, schools, supermarkets, churches, many types of commercial and industrial buildings — and the modern shipping container.

FPL research in this area begins with the establishment of the mechanical, physical, and related properties of the many species of wood commercially used, and the effects of use conditions on these properties. The same properties and conditions are investigated as they apply to plywood, laminated wood, chemically treated wood, fiberboard, particle board, paper and paperboard products, and composites of wood and other materials.

Basic data on materials thus assembled are developed into criteria for use in structural design. A familiar example is the bending stress rating assigned to a given grade of a particular species of framing lumber by manufacturers' groups, typically the 1900f rating assigned the Select Structural grade of Douglas-fir beams and stringers by the West Coast Lumber Inspection Bureau.

FPL research engineers consult on questions of design criteria, grading rules, codes, and standards with private industry groups, such as the National Lumber Manufacturers Association and its regional affiliates, the American Institute for Timber Construction, the Douglas Fir Plywood Association, the Association of American Railroads, the American Standards Association, and the American Society for Testing and Materials. Committees of some of these organizations include FPL staff members. Others maintain committees that keep in close touch with FPL programs and findings.

Structural research ranges from the simplest joints and fastenings to full-scale structures, their walls, floors, roofs, and elements such as trusses, arches, and panels. These are loaded in various ways to simulate actual stresses imposed during use and conditions of use.

Package engineering is a longtime FPL specialty. It embraces the design and fabrication of improved boxes, crates, and pallets, blocking, bracing, and cushioning of container contents, and associated protective measures such as waterproof and greaseproof containers and wraps.

Basic Engineering Properties

The forerunner of what is expected to be a major re-examination of important western species got under way during 1961 with a study of the basic strength properties of white fir (*Abies concolor*). This re-examination will be done as part of an overall survey of the quality of standing timber in various parts of the United States, as discussed elsewhere in this report under the major research area heading, "Wood Quality Research."

The white fir strength investigation is being conducted on wood from two locations in Oregon and two in California. The logs being used came from trees from which alternate logs were at the same time shipped to the Douglas Fir Plywood Association laboratories in Tacoma, Wash., for concurrent investigation of the mechanical properties of veneer and plywood made from them.

Ultimately, DFPA plans to relate its results to those of FPL, the object being to determine the relationship between strength properties of commercial plywood and the basic properties as found for the clear wood by standard procedures. The closely matched wood specimens from alternate logs of the

Hands in rubber gloves, Technician William Brewer adjusts specimen through portholes of air-conditioned chamber before imposing tensile load. Gloves permit manipulation without opening chamber.

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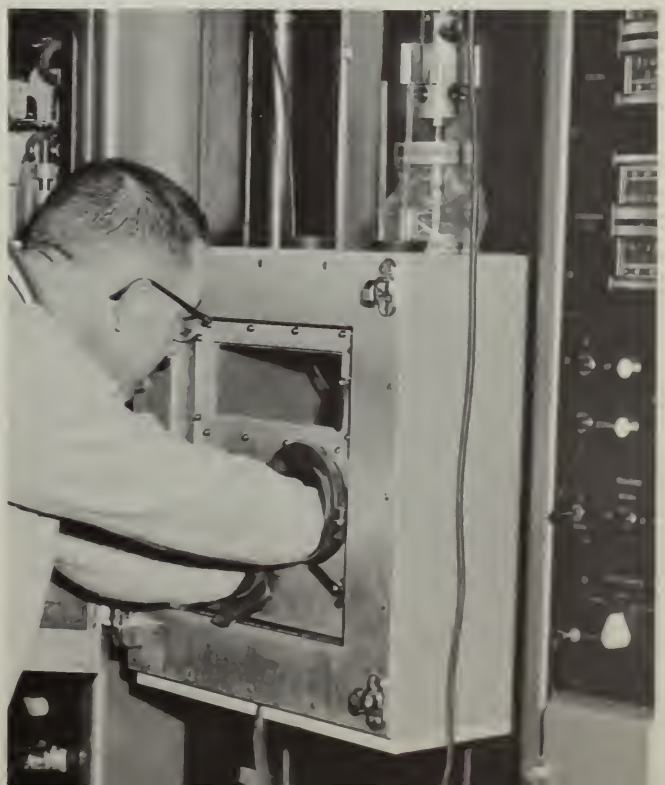


same trees being used at both FPL and DFPA are expected to facilitate this investigation.

For species other than white fir, existing strength values will be re-examined on the basis of a comparison of existing specific gravity data and values obtained from specific gravity determinations of standing trees statistically selected to give a far more comprehensive sampling of each species than has hitherto been possible. This broad sample may lead to further investigations of some species to determine conclusively the validity of existing strength data or modify them.

FPL evaluations of white fir wood are still in the preliminary stage, and no firm results on either green or air-dry material are yet available.

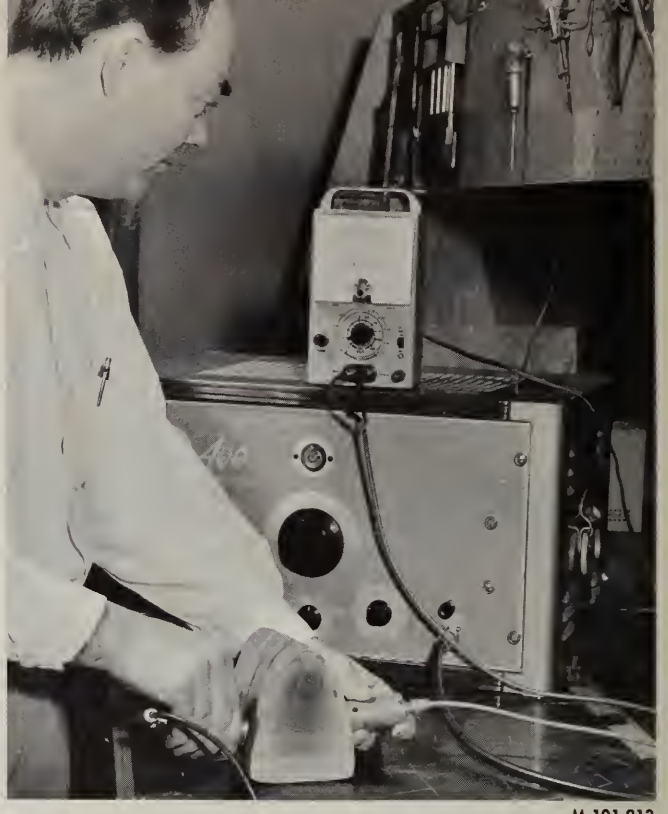
Two lesser species, Osage-orange from northeastern Oklahoma and a hybrid of Monterey pine (*Pinus attenuradiata*) from the Institute of Forest Genetics at Placerville, Calif., were evaluated. The Osage-orange was generally stronger than wood of this species previously obtained from outside its natural range. The strength of the hybrid was only about one-half what would normally be expected on the basis of its specific gravity, possibly because of appreciable amounts of compression wood.

Under evaluation is a Hawaiian hardwood, *Eucalyptus saligna,* that is considered to have potential as a structural species for use in that State.

Research on quarter-scale bridge stringers showed that present methods of deriving working stresses give adequate margin against bending fatigue failure in service. The work was done in cooperation with the Association of American Railroads on southern yellow pine and Douglas-fir. A need for further consideration of allowable shear stresses was brought out, however, especially for preservative-treated stringers.

Evidence that fire retardants reduce flexural strength and stiffness of wood was obtained in experiments on southern pine and Douglas-fir treated with two kinds of commercial retardants. This work prompted a more fundamental study that is designed to evaluate individually the effects of various chemicals and treatments on the strength of different species. Industry groups are supporting this work.

Basic research on the physical properties of wood was continued, with a major object the development of nondestructive tests that reliably measure strength. With such a test, simply, conveniently, and quickly made at the sawmill, each piece of structural lumber from 2 by 4's on up to giant timbers could be assigned a realistic strength value. At present, by contrast, grading for strength is done on the basis of visual estimates of the proportion of summerwood, rate of growth, slope of grain through the piece, and the location and size of knots and other strength-reducing characteristics.



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Physicist William L. James passes ultrasonic vibrations through seasoned hard maple shoe-last blank as nondestructive means of finding drying defects before costly carving exposes them.

One type of nondestructive test that shows promise of commercial application consists of measuring the rate at which vibrations along the length of the piece are damped off. By this means a measure of internal friction and resonant frequency of a piece of wood is obtained on an oscilloscope. Resonant frequency has been shown to be closely related to modulus of elasticity, and internal friction has about the same relationship to strength as does specific gravity.

A few exploratory studies were begun, with equipment borrowed from the Association of American Railroads, to determine whether it is possible to evaluate specific gravity and moisture content of wood with radioactive isotopes. Voids in wood less than 5 inches thick were located and measured by counting escaping thermalized neutrons from a radium-beryllium source or by counting backscatter and transmission of gamma rays from a cesium 137 source. Gross differences in total mass, including moisture and wood substance, were found to be detectable.

Laminated Construction

Among the first glued laminated structural members ever built and erected in the United States are the arches that support the walls and roof of an auxiliary laboratory structure on the FPL grounds. Erected in 1935, this building has been recognized as a pioneering venture by the industry that has since sprung up on the basis of the technology originated largely by FPL research that has been continued as needed ever since.

Work is under way in cooperation with the Association of American Railroads on evaluations of the behavior of full-sized glued laminated bridge stringers under repeated loading. Tests are being conducted in the AAR laboratories. FPL engineers are advising on the analysis of results, and obtaining basic data on properties of the wood used in the stringers.

For the Navy Bureau of Ships, flexural strength of laminated Douglas-fir beams that had been immersed in salt water was investigated. Neither strength nor stiffness was found to be significantly affected by up to 9 million cycles of loading to 45 percent of estimated maximum strength.

Plywood Strength

Although the strength properties and engineering criteria of plywood have been deeply studied at FPL over a period dating back to World War I, the broad use of this material today frequently brings up new questions requiring laboratory investigation. Industry and government agencies such as FHA often bring such problems to FPL for exploration and solution.

For example, a major producer of missiles requested information about plywood as a structural cylindrical shell in a missile. From the ensuing study was developed a mathematical analysis for the buckling of such shells under external radial pressure and experimental data closely verified the mathematical theory. Design data for buckling coefficients were derived.

The dramatically different structural designs for which plywood is used — vaulted roofs, multicurved shapes, space planes and the like — also bring up design problems. Deflection studies of flat plywood under load, for example, disclosed that failure can occur in compression at the panel edges rather than in flexure. A theory for predicting such behavior in mathematical terms is being developed for designers.

Fiberboard and Particle Board

A major investigation of the strength of hardboard, other fiberboards, and particle board was launched during 1961. These materials have come into extensive use for structural purposes, and for these uses their strength and related properties needed to be more precisely defined by research. The work begun last year is expected to continue for 4 years, and since its inception has won cooperative support of the American Hardboard Association.

The program contemplates evaluation of plastic and elastic behavior under various kinds of loadings, effects of duration of stress, fatigue, and rate of loading, and time-temperature-moisture content relationships for hardboard and building fiberboard. Procedures for adequately measuring shear strength in the plane of the panel, a property important where a panel is used as a stressed skin or structural sandwich facing, are under development.

Structural Utilization

The evaluation of structures and structural elements made of wood and wood-base materials constitutes an important and growing field of FPL engineering research. Based primarily upon design considerations, it logically starts with the development of stress grades and working stresses, species effects, and design criteria from the basic strength data for materials. Joints and fastenings, structural elements such as trusses, arches, and various types of structural panels, and overall evaluation of complete structures are included in this research.

The determination of basic stresses for native species is an assignment undertaken by Committee D-7 on Wood of the American Society for Testing and Materials. FPL engineering personnel serve on this committee, which is revising basic stresses. Also under consideration by the committee are proposals for deriving working stresses directly from strength surveys rather than first developing basic stresses for clear wood and applying limiting factors, such as quality of material and safety, to these. Progress in the development of nondestructive tests for stiffness and strength lends validity to these proposals.

Stress grades and working stresses for railway structural timber are being reviewed in cooperation with the American Railway Engineering Association. AREA was assisted in evaluating shear stresses in bridge stringers under Diesel locomotive loads.

A lengthy and complex investigation of the strength of wood poles was completed with the issuance of a report on results to the cooperator, ASTM. This report has been sent to the American Standards Association, with which FPL is cooperating on revision of "American Standard Specifications and Dimensions for Wood Poles," primarily to develop a schedule of fiber stresses and establish defect limitations. The object of this program is to provide a more comprehensive basis for engineering evaluation of poles of major species for use by utilities.

More efficient designs for timber highway bridges are being developed cooperatively with the Division of Engineering of the Forest Service. A mathematical theory developed for calculating stiffness of a three-stringer bridge checked out with experiments in the laboratory, and a general analysis for the stiffness of a multistringer bridge was completed.

Five bridges on Forest Service highways were load tested to measure deflections in the supporting beams and stringers. One of these was in Georgia, three in Montana, and one in Oregon. Meantime, a

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Heavy wood bridge stringer under torsion load imposed at both ends to produce twisting stresses.

supply of full-size timbers was obtained and material tests begun in preparation for later study of full-scale bridge assemblies loaded to destruction.

An investigation of the load-carrying capacity of multiple-bolt joints in heavy Douglas-fir timbers showed that each bolt carried 80 to 90 percent, on the average, of the maximum load supported by a single-bolt joint. In green lumber, multiple-bolt joints carried only about two-thirds of the load comparable joints supported in dry material. In green material allowed to season before final evaluation, strength parallel to grain was somewhat higher and strength perpendicular to grain somewhat lower than in material tested while green.

Under way is an investigation of multiple-bolt joints in laminated members that consist of laminations differing in specific gravity. The question is, how do these joints compare with similar ones in solid timber? Effects of bolt spacing in the joint are being studied.

Trusses of two types, which had been evaluated when made and then stored outdoors, were reevaluated 4 years later for aging effects on their joints made with plywood gusset plates glued in place. King-post trusses underwent no strength or stiffness deterioration. In trusses of W design, strength was also maintained but stiffness declined 10 to 15 percent. The rolling shear strength of individual joints was found to be 30 percent lower than that of joints with unweathered plywood gussets. Results led to the beginning of an extended study on nail-glued plywood joints extensively used by the building industry in trusses for houses and other structures.

Structural research on housing recently has been focused on the performance of materials and structural elements under normal service conditions. To obtain more accurate data on such conditions, a survey was completed during 1961 on temperature build-ups within houses. The data had been taken in houses at Tucson, Ariz., Athens, Ga., Portland, Oreg., and Lufkin, Tex., as well as Madison, Wis.

Working with FPL in this survey were the Rocky Mountain, Pacific Northwest, and Southeastern Forest Experiment Stations, the Texas Forest Service, and the University of Arizona.

Data showed maximum roof temperatures up to 160°F. Surface texture and color of roofing were found to have pronounced effects on temperature, and the value of attic ventilation on keeping temperature down was strongly confirmed.

In 1948 the Laboratory built an experimental house-like structure with walls and flat roof of sandwich panels with paper honeycomb cores and facings of plywood, hardboard, cement-asbestos board, and metals. Last year one panel with cement-asbestos facings and one with hardboard facings were taken out for examination of aging effects. Both were stiffer than matched panels tested new in 1948. Aging had cost the hardboard-faced panel 7 percent of its strength when new and the cement-asbestos panel 17 percent.

Packaging Research

The cost of protecting goods in transit and in storage bulks sufficiently large in the industrial economy to warrant major efforts toward greater efficiency. Packaging research in the past has rung up many noteworthy economies by reducing weight and cubic content of packaged items and designing stronger, more efficient packaging systems with less material more judiciously employed. In war and peace, for industry and for the military, FPL contributions in this field have been many during four decades of pioneering work that transformed packaging from a hit-or-miss guessing game to an engineering specialty.

Among many examples of this evolution to professional maturity, the most evident today is the fiberboard box. Packaging specialists are careful to specify "corrugated fiberboard," and with good reason. Today's corrugated container is a far cry from the old "cardboard" box — it is made of material as carefully engineered for specific jobs as a beam, a truss, or an arch. Thickness and weight of paperboards have been closely related to various strength properties, and the combinations of liners and corrugated sheets have been standardized on the basis of paper properties into structural elements of known strength and stiffness. Thus the load-carrying capacity of a shipping container becomes as mathematically certain as that of a truck or freight car. FPL research contributed greatly to this evolution.

Typical of this research is a study in progress since 1940 of the stacking loads that can be sustained by corrugated fiberboard boxes in longtime warehouse storage. One phase currently under investigation is the effect of different types of box contents. Three kinds of contents are under study; one prevents box sides from bowing in; a granular type "flows" as the box is deformed; and one of water in a flexible barrier also flows, but with less restraint than the granular type. Effects of each type will be analyzed to determine how it affects the resistance of the box to stacking loads encountered in storage.

Another study deals with the most efficient distribution of wood fiber in corrugated board. Corrugated board was made in the laboratory from liners and corrugating mediums of various weights. Results indicate that weight added to the liners produces more strength than when an equivalent amount of weight is added to the corrugated section.

Numerous inquiries about the effects of age on paperboard and corrugated fiberboard boxes prompted a re-examination of paperboards first evaluated when new 25 years ago. Strength properties were unchanged. Boxes 2 to 10 years old were about 5 percent stronger in compression than when new.

Research on package cushioning is aimed at evaluating various materials of both wood-base and other origins. Dynamic testing equipment had to be designed for this pioneering work. Illustrative of instrumentation problems that crop up is that of a suitable loading pendulum for testing corrugated fiberboard cushions. The nature of the cushion is such that, when it is impacted, a ringing effect is produced that distorts the electronic load-recording pulses. This effect has been traced to the design of the pendulum head, and corrective designs are being investigated.

Research made possible a noteworthy advance in the design of bin pallets, now widely used for harvesting and shipping apples, citrus fruits, and some types of vegetables. An evaluation of 11 bin-pallet designs by means of simulated weathering and rough-handling tests demonstrated desirable construction features, and results have been widely published among users of agricultural bin pallets.

A collapsible wood bin pallet was designed in cooperation with the Agricultural Marketing Service of the U.S. Department of Agriculture and put into service tests by a grocery chain for experimental transport of potatoes from growers to terminal markets.

For the Air Force, 16 types of lightweight pallets were evaluated by simulated rough-handling tests. The tests will become part of a new specification for expendable pallets, and four designs of pallets are to be tried out under actual air cargo shipping conditions by the Air Force.

At the Carbondale, Ill., Research Center of the Central States Forest Experiment Station, 90 pallets made of green and dry lumber are being periodically inspected while in service. After 2 years, edge deck board of green lumber are showing considerably more failure than those of dry lumber, and there is much more objectionable protrusion of nail heads.

Adhesives for Box Assembly

Several adhesive materials have been found promising enough, in evaluation of some 30 combinations of plastics, adhesives, and mastics, to warrant investigation of their performance in vegetable and fruit lug boxes. One of the best is a rubber isolator glued

between box parts. A seam compound and a castor polyol type of adhesive were found to be nearly as good in evaluation of simulated box corners under impact loading that imposed tension, shear, and spreading forces on the joint.

Fasteners for Blocking, Bracing

The dynamic loading capabilities of nails, lag screws, and bolts were examined with pendulum-impact type apparatus to establish requirements for fastening blocking and bracing in place in crates to prevent shifting of contents during transit. Blocking and bracing are also used to restrain movement of containers and heavy equipment shipped on railroad cars and other cargo carriers. Special electronic equipment was devised to observe, measure, and record reactions to dynamic forces imposed on the fasteners.

Nails, lag screws, and bolts all tended to follow the same pattern under dynamic shear loading and resultant joint slip. Fastener diameter appeared to be the controlling fastener characteristic. Indications were that loads imposed on nails should be limited to about one-half the calculated allowable load under long-time loading to restrict lateral slip to about 0.3 inch, which is considered necessary for proper restraint of the load being blocked or braced.

Packaging Specifications

Because of its long-standing role in packaging research, FPL is widely consulted by other government agencies concerned with packaging and shipping specifications. Currently an extensive job of standardizing packaging test procedures is being done for the Navy Bureau of Naval Weapons. More than 1,400 test procedures have been extracted for review from some 335 government packaging specifications; each is referred to the most qualified member of the FPL staff for review and improvement. After military coordination and acceptance, they are included in Federal Standard No. 101.

Packaging Cost Manual

A manual recently completed by FPL to aid Air Force packaging and procurement personnel in estimating costs of packaging is being given trial use by the Navy and the Army Ordnance Corps. Estimates of impressive savings through its use have been received. In one 10-month period, Air Force savings on procurement contracts reportedly amounted to $2,243,000. A West Coast packaging consultant said that $247,000 was refunded to the Air Force on one contract on which he had used the cost manual. Assistance was given the Joint Military Packaging School in preparing a training course on use of the manual.

Wood Fiber Products Research

Year by year, more and more wood is transformed into substances whose origin in trees is unrecognizable. Wood is our main source of fiber for myriad pulp and paper products, the demand for which continues to mount. By 1975 it is expected that 40 percent of all wood used will go into these products. As a result, greater pressure is put on our timber supplies and research is called on to broaden raw material supplies.

Ever since FPL was founded, pulp and paper has been one of its major fields of research, and this continues to be the case. An intensive program is carried out on pulping processes, on wood fiber properties related to pulp and paper production, and on the manufacture and properties of paper products. The object is to make hitherto unused species and qualities suitable and to produce more pulp from less wood.

Chemical Pulping

From its beginnings, the pulp and paper industry has relied most heavily on softwoods — the firs, spruces, pines. Fully delignified pulps of these long-fibered species are still most commonly used in many grades of paper and are in ever-increasing demand. Anticipated shortages, therefore, are heightening interest in more efficient pulping methods. Three processes under FPL investigation hold promise of greater pulp yield from softwoods.

One, the polysulfide process, is under study to increase the efficiency of southern pine kraft pulping. It consists essentially of adding polysulfide to kraft liquor. In the laboratory, it promises 15 percent more pulp than is obtained by straight kraft pulping from the same amount of wood. Such savings would mean substantially lower pulpwood costs and a $2- to $4-million saving in capital cost of a 300-ton, $25-million kraft mill.

A drawback, excessive use of sulfur, is being attacked in continuing research. Injection or two-stage cooking appears to promise reduction of sulfur loss to levels now common in kraft pulping. The basic reaction mechanism of elemental sulfur and polysulfides is under intensive study.

The bisulfite process was investigated for production of newsprint and printing papers from softwoods. Pulps obtained were much stronger and cleaner than those produced by regular acid sulfite pulping. Yields of 55 to 60 percent also were appreciably higher, and the pulps were bleached to moderate brightness.

The alkaline sulfite process is being evaluated for semichemical pulping of softwoods. Bleached spruce pulps were considerably higher in strength and yield than kraft pulps of the species. Possibilities of lowering lignin content and bleach requirements are being studied.

Semichemical and Chemimechanical Pulping

Semichemical pulping was pioneered during the twenties by FPL as a means of utilizing plentiful hardwoods much more extensively. The original neutral sulfite semichemical process has been notably successful toward this end. Moreover, it has spawned related processes, both acid and alkaline, and a new, more accurate generic term, "chemimechanical" processing. The processes are characterized by high yield, including substantial amounts of lignin. One of

Technician John F. Wichmann inserts paper specimen in jaws of testing machine to determine tensile strength.
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the newest is the FPL cold-soda process, which effectively doubles pulp yield as compared with the true chemical processes.

Cold soda pulping continues to gain interest in the industry, and new equipment for fiberizing caustic-treated chips has been developed commercially. Pulps made from aspen and a mixture of eastern hardwoods in one new type of fiberizing machine were successfully used to replace lower yield chemical and semichemical pulps in fine papers.

The high yields obtained from hardwoods with chemimechanical processes have led to trials with softwoods. In many paper and board grades, length of fiber is the prime requisite, color and physical properties being secondary. At current production rates for unbleached pulps, each 1 percent increase in yield attained by including more lignin is worth $16 million a year — an excellent value for lignin normally burned or otherwise disposed of! The substitution of semichemical for chemical softwood pulps in unbleached papers thus promises not only more complete utilization of wood but profitable utilization. FPL research is seeking to broaden the utility of semichemical softwood pulps even more by improving pulp color and strength.

Further improvements in high-yield pulping are being sought through basic studies of the mechanism of wood fiber separation. The goal is better treatments for removing the lignin-rich outer layers of cell walls from the carbohydrate-rich inner layers. Chemicals are being tried that cause the outer layers to swell differently than the inner layers, thus easing the problem of mechanical separation in a refiner. Fluorescence microscopy, which reveals in fine detail the surface structure of fibers, is being used to detect how effective treatments are in causing separations within the fiber walls.

Bleaching Cold Soda Pulp

The caustic soda liquor used to soften hardwood chips for fiberization in refiners darkens the resulting cold soda pulp. Experimental addition of sodium hypochlorite, a bleach, to the liquor brightened the pulp enough for newsprint use. Additional bleaching with peroxide while the chips were being fiberized brightened the pulp enough more for use in boxboard and some foodboards. A final treatment with hydrosulfite in a bleach tower made the pulp bright enough to use in magazine papers. A cost study indicated that the convenience of the first bleach step was at least partially offset by a cost $3 per ton higher than conventional batch bleaching with peroxide.

Fiber Bonding

As pulp passes through the paper machine, it is dried and pressed by rollers to form paper. The drying process causes the fibers to shrink together, forming bonds between hydroxyl groups that are largely responsible for sheet strength. The amount of bonding depends largely on the external surface area of the fibrous mass. Pulp processing, such as beating, increases the surface area, thus improving fiber bonding and sheet properties.

A water-permeability method of measuring surface area was found useful for measuring the improvement gained from beating the pulp. Surface area of an oak kraft pulp moderately beaten, for example, was increased from 12,500 to 58,000 square centimeters per gram of pulp. Bursting and folding strength of papers showed steady increases with increases in surface area brought about by beating and screening to remove fines (greatly undersize cells, vessel elements, and fiber fragments).

In another study of the effects of pulp beating, too rapid jordaning — a continuous process of beating as opposed to batch processes — was found to impair paper quality. As production rates were speeded up, fibers appeared to be shortened enough to offset the gains in bursting and tensile strength normally obtained by beating at slower production rates.

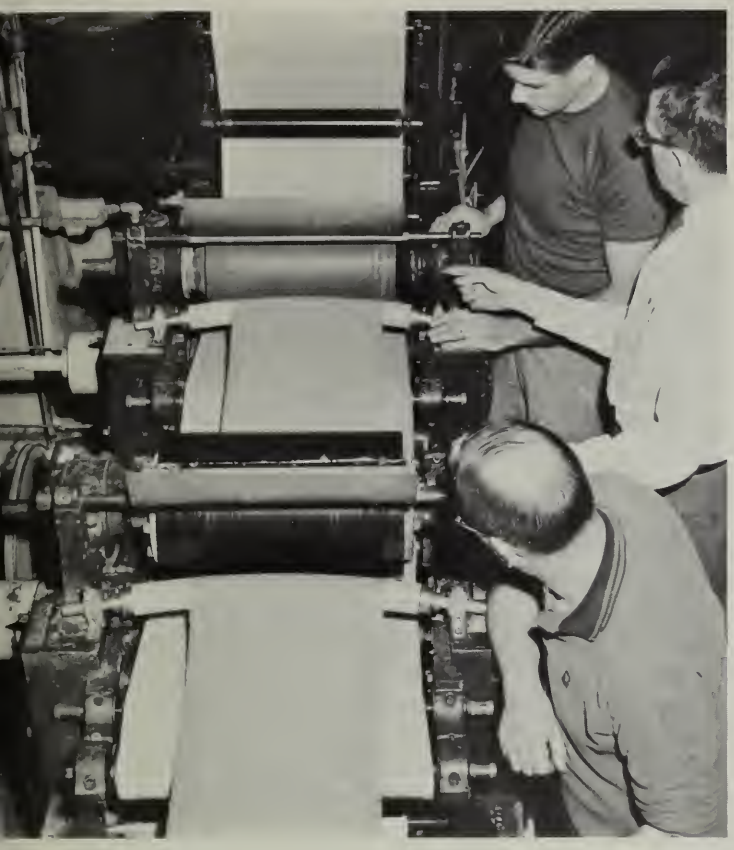
Paper Manufacture

Hardwood semichemical pulp was successfully substituted for up to 60 percent of the kraft softwood pulp generally used to make linerboard — the facings for corrugated sheets in container board. Semichemical pulp heretofore has been used only in corrugating medium. The experiments were followed up with pilot runs on a commercial machine and production of boxes that had adequate top-to-bottom compressive strength but somewhat lower impact resistance than boxes with all-softwood kraft liners. Research is continuing on ways to make the hardwood liners more impact resistant.

Research on paper production processes and treatments opened the way to significant improvements in strength, stiffness, and dimensional stability of papers ranging from container board to sorting machine punchcards and map and color printing papers.

Among various chemicals tried for stiffening container board to improve stacking qualities, a 10 percent impregnation with phenolic resin offered most promise. The resulting board had compressive strength at 90 percent relative humidity equal to that of an untreated board at 50 percent. Wax emulsions and some water repellants were entirely unsatisfactory. A surface application appeared to be better than complete penetration of the chemicals. Surface application was done best at the size press on the paper machine, where the sheet is practically dry.

Significant gains in stiffness and strength of container-type papers were achieved by restraining the wet web on the paper machine from shrinking as it dried. The greater the restraint, to the point of ac-



M 101 199

Pulp web moves over expander rolls of FPL paper machine in experiments to improve stiffness, dimensional stability.

tually stretching the web, the greater were the gains in strength and stiffness. Stretching was accomplished on the paper machine with a commercial type of expander roll normally used to prevent wrinkling during manufacture and winding of paper. The curved rolls exerted a sidewise pull on the web that tended to broaden it. With several rolls in the press and dryer sections of the machine, a sheet was obtained that was actually wider at the reel than at the wet end of the paper machine. The Boxboard Research and Development Association cooperated in this work.

In related studies, restraining the shrinkage of paper sheets during drying was also found to result in a sheet more dimensionally stable with changes in relative humidity. Dimensional changes can cause serious production and operating troubles with punchcards, maps, charts, and paper for color printing. Shrinkage during sheet drying was found to be more important to dimensional stability of paper than pulp type, wood species, or degree of processing of the pulp.

The same type of expander roll used to stiffen paper was highly successful in improving dimensional stability. A sheet made from processed bleached softwood sulfate pulp stretched on these rolls was 9 percent wider (9 inches more on a normal 100-inch sheet) and 55 percent more dimensionally stable when exposed to humidity changes. There was no significant loss in sheet strength such as often accompanies the use of chemicals to stabilize such papers

Wood Chemistry Research

Chemical conversion of wood into other products, while extensive, has by no means tapped the full riches of this raw material. The reasons are varied. Wood cellulose, which comprises some 60 percent of wood substance, has been heavily used in a number of products from rayon to photographic film and explosives. Similar utilization of lignin, the cement-like amorphous substance that constitutes about 30 percent of wood, has been balked, however, by the difficulty of removing it from wood unchanged. Even its full chemical characterization remains to be established. Consequently, the foremost challenge to wood chemists today is the nature and utilization of lignin. The material benefits are potentially enormous.

An important segment of chemical research at FPL is that on lignin and the extractives of wood and bark. Studies on cellulose and carbohydrate comprise another important part of this basic research, with a principal object the utilization of grades, qualities, and sizes of wood not acceptable for solid wood or fibrous products. Development of more efficient chemical processes is being pushed and involves such basic ones as hydrogenation, hydrolysis, and destructive distillation, as well as bacterial fermentation and other biochemical methods. Dimensional stabilization and surface properties of wood comprise major physico-chemical lines of investigation.

Lignin Chemistry

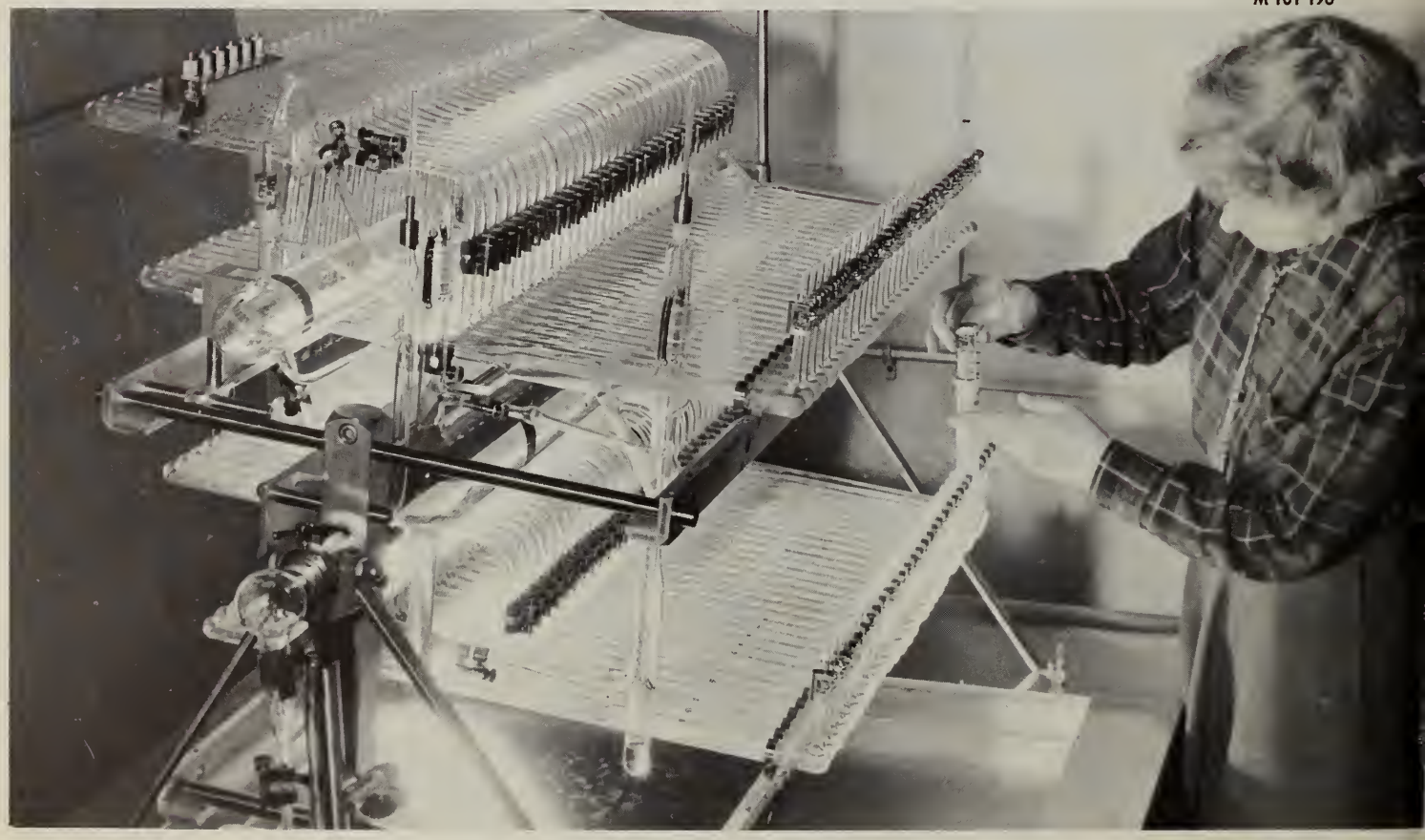
The lignin dissolved in pulping liquors has a number of uses. The spent liquor from sulfite pulping and its counterpart, the socalled "black liquor" from sulfate (kraft) pulping, are both processed to some extent to recover useful compounds. Uses include application as a dispersing agent; replacements for carbon black in rubber; boiler water conditioners, and oil-well drilling muds. Sulfite liquor lignin is additionally used as a roadbed stabilizer, for production of yeast, vanillin food flavoring, and alcohol.

The tonnages of lignin removed from wood by pulp mills, however, are so vast that existing uses consume only a small fraction. The bulk is burned for heat and to recover pulping chemicals, or is even less usefully disposed of.

Research on the possibility of obtaining other simple, potentially useful compounds from black liquor is under way at FPL. Anticipated products include alkyl-substituted phenols, methoxy phenols, and

Craig countercurrent extractor in use by Dr. Margaret Seikel to separate flavanoids from mixture in solution.

M 101 196



a series of catechols. New microkinetic techniques will be used to gain estimates of quantities potentially available.

Long-term basic research aimed at more complete characterization of the lignin molecule, however, offers the best hope for ultimate large-scale utilization of this chemically elusive substance. Being sought is a more precise description of lignin as it occurs in the tree. Progress is being made.

During the past year, for example, FPL workers reported that experiments with synthesis of complex model compounds yielded evidence that biphenyl-linked building units account for perhaps 30 percent of the lignin molecule. Work is going forward on means of separating products that may contain biphenyl linkages, which are especially resistant to cleavage into simpler compounds.

Experiments with hydrofluoric acid as a reagent in separating lignin from other chemical constituents of wood yielded an especially effective method of preparing wood sections for microscopic study. The acid was found to remove everything but the lignin, yet leave the three-dimensional structural features of the wood intact. Findings of study under the electron microscope are presented in the section of this report entitled "Wood Quality Research."

Chemical Process Development

A new process was developed for cellulose nitration, and a patent was obtained. Nitration is accomplished by treating cellulose with anhydrous mixtures of nitrogen tetroxide and hydrofluoric acid. The process may lend itself to continuous production of cellulose nitrate in sheet form, and has some advantages in the ease with which it can be stabilized.

The low-temperature behavior of solid rocket fuels containing nitrocellulose was studied for the Army Ordnance Corps and a report on findings submitted.

Research on a dehydration process for making furfural from the xylose fraction of hemicellulose has shown that the process is economically as well as technically feasible if the hemicellulose fraction bears only its proportionate share of the wood cost. Furfural is used in resin manufacture, as an extracting solvent to purify lubricating oils and gasoline, and for other purposes. It is now made from corncobs and bagasse.

Technical production problems were explored in a pilot-scale preheater-reactor unit. It was found that solutions containing hexose and pentose sugars can be fermented to alcohol, processed to convert the pentoses to furfural, and the alcohol and furfural can be recovered in the same still with marked economy in use of equipment and steam. Such a process can be attractive under the proper circumstances.

Using a highly efficient experimental technique, valuable processing data were obtained on the delignification of aspen wood with sodium xylenesulfonate, a hydrotropic salt. Measurements were taken of the effects of varying salt concentration, catalyst acid concentration, and temperature upon the rate at which lignin and hemicellulose were removed and upon the composition of the residue.

An extensive program of research on charcoal production, carried out by FPL in cooperation with the Lake States and Southeastern Forest Experiment Stations, was completed with publication of a joint report. Data are given on marketing and use as well as on production. Kiln design and operation are stressed.

Biochemical Production of Chemicals

Research on the conversion of wood sugars to useful chemicals by fermentation with osmophilic yeasts is being pursued with two specific chemicals of considerable potential commercial use as the principal targets. On one, erythritol, laboratory work was nearly completed and has attracted some commercial interest. This polyol is a rare chemical, sells at a high price, and must be imported. At lower prices, however, it can be expected to find promising uses in plastic resin and coating formulations.

The other fermentation study, just under way, aims at production of itaconic acid from hexose and pentose sugars. This dibasic acid is of commercial interest for certain types of plastics because it can react both through its carboxyl groups and its double bonds.

Bacteriologist Barbara Spring intently watches flasks containing xylose solution and mold *Aspergillus terreus* being vigorously shaken to introduce air into solution during fermentation for production of itaconic acid.

M 120 952

New Analytical Methods

FPL's chromatographic method of analyzing purified pulps for trace carbohydrates formed the basis for a tentative standard of the American Society for Testing and Materials. The method is widely used in this country and abroad.

A spectrophotometric method for determining the lignin content of wood in small samples was published in TAPPI, the journal of the Technical Association of the Pulp and Paper Industry. A 0.010-gram sample of wood is dissolved by treating it with acetyl bromide in acetic acid, the solution is treated with chemicals to remove interfering substances, and lignin content is computed from the amount of light absorbed by the solution at a wavelength of 280 millimicrons. Measurements are reproducible, rapid, and inexpensive.

Physical Chemistry

Research on the physical chemistry of wood is mainly devoted to investigation of phenomena involving the surface chemistry of wood, wood-water relations, dimensional stabilization, colloid chemistry, and adsorption of substances on wood. Among these, stabilization treatments that counteract the dimensional changes that occur in wood as it shrinks or swells with changes in atmospheric humidity continue to receive much attention.

One current goal of dimensional stabilization research is a simple process that will do an acceptable job with little chemical at low cost. Such a process would be applicable to many large-volume uses of lumber, plywood, and fibrous sheet materials used in millwork, sash and doors, furniture, and other uses. Its development appears to hinge on the extension of basic knowledge about such things as the effectiveness of films as moisture barriers and the mechanism of moisture passage through wood.

Polyethylene glycol, a waxlike chemical that dissolves in water, was found several years ago to be a good stabilizing agent when introduced into the fine cell-wall structure of green wood. Its use in this respect and as an aid in the seasoning of wood is described in the section of this report entitled "Solid Wood Products Research."

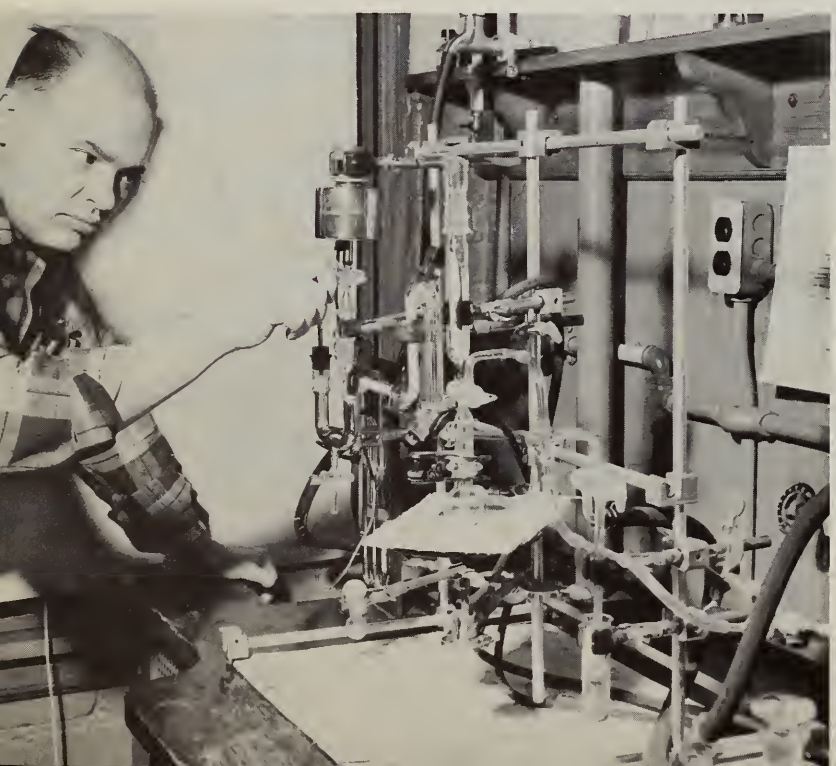
A nuclear magnetic resonance technique was found to be useful for measuring the relationship between moisture content and the tightness with which moisture is bound to wood. The extent to which a wood specimen placed between poles of a magnet absorbs radio-frequency radiation is measured and correlated with the moisture content of the wood.

The same technique was used experimentally to relate mobile hydrogen content of wood and moisture content. Since the relationship is not limited to moisture content levels below the fiber saturation point, the method appears to have possibilities for nondestructive measurement of all moisture levels. Equipment limitations at present make it more suitable for chips and pulp than for solid wood.

In a study of the surface properties of wood, a specific affinity was found to exist between polyvinyl acetate and wood surfaces. Adsorption of this polymer was found to be greater in swollen wood, and the lumen walls of wood were shown to play an important role in the adsorption. Exploration is continuing on the factors that affect the bonding of such polymers to wood.

Chemist Richard C. Weatherwax collects gas from burned polyvinyl acetate tagged with radioactive C-14, to measure amount adsorbed on lignin surface.

M 101 217



Apparatus for measuring C-14 content of gas obtained in burning polyvinyl acetate coating adsorbed on surface of lignin film.

M 101 218

Wood Quality Research

The quality of standing timber bears importantly upon the cost, strength, durability, beauty, and other criteria by which wood products are judged. Research aimed at improving the quality of wood and its products, therefore, begins in the forest, where wood is essentially "manufactured" by natural life processes.

The key role that wood utilization research plays in this area of quality has been increasingly recognized in recent years by foresters, timber owners, lumbermen, plywood producers, and makers of wood fiber products. Rate of growth, density, fiber content, and other basic indicators of wood quality are all governed to a great extent by growth conditions in the forest, and these conditions are in turn proving manageable to an extent that heavily influences the quality of the wood produced.

The objects of FPL research affecting wood quality are to establish and apply criteria needed to evaluate quality of existing timber resources; to evaluate growing conditions and forest management practices in terms of wood quality; to explore the significance of the complex structure of wood with respect to strength and related physical properties; and to establish working principles and procedures for evaluating wood and wood products in terms that facilitate better grading for quality.

In line with these objects, research is under way to evaluate the intrinsic wood quality of standing timber; establish what effects such environmental factors as soil and rainfall, and such silvicultural treatments as pruning, have on quality; investigate by microscopic and other means how the physical structure of wood is related to its properties; and assist in the establishment of quality grades for trees and logs.

Quality of Standing Timber

Over the years, FPL research has developed a number of basic criteria for judging the quality of wood. Among these are the number of annual rings per inch of radius of a cross section; proportion of summerwood in the annual rings; the angle at which the fibrils of a wood fiber are oriented to the longitudinal axis of the fiber; and specific gravity.

Of these, the most broadly useful index to such quality factors as strength, hardness, and associated physical properties is the last, specific gravity. It is also a reliable indicator of fiber content, a quality factor of prime interest to pulp and paper manufacturers.

A few years ago the Forest Service was about to begin another of its periodic timber inventories in certain States. To conduct this work, foresters select sample plots on a statistically sound basis and estimate timber volume of the trees on them. These estimates are used to calculate board foot volume of standing timber on all forests in the geographic area sampled.

As an experiment, the Southern Forest Experiment Station agreed to include a "density survey" of southern pines on all sample plots to be inventoried in the state of Mississippi. That is, a specimen of wood called an increment core would be taken from each tree at breast height and sent to FPL for specific gravity determination. In this way a statistically reliable estimate of the density of the southern pines of an entire State would become available for the first time. When Mississippi State forestry officials and industry representatives were informed of what was contemplated, they agreed to furnish manpower and other help.

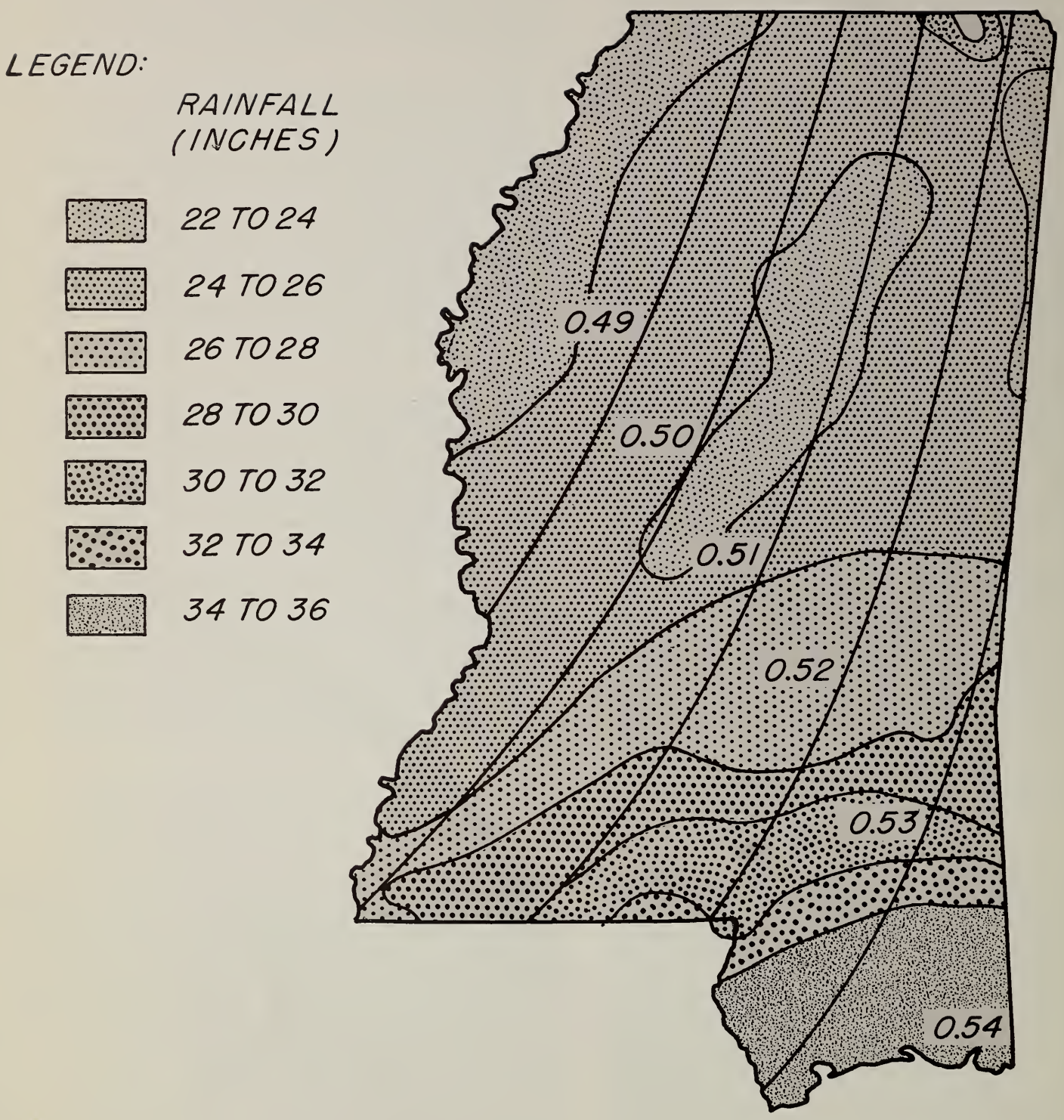
The Mississippi density survey provided a wealth of information on not only the density range of southern pine in that State but on density variation with geographic location, growth conditions, climatic factors, and the like. In addition, the cores proved useful for other evaluations, such as rate of growth and fibril orientation.

An extra bonus was the location of trees with wood of exceptionally high quality for seed collection and genetic study by specialists of the Southern Station. One longleaf pine with a specific gravity of 0.75 — highest on record for any native softwood of good form and growth rate — produced twice as much fiber as average trees the same age on the same site. Some of these elite trees may become the parents of superior forests.

Since completion of the Mississippi "quality census," similar work has been undertaken in other southern States. Core collecting and processing had been completed by 1961 for Missouri, Arkansas, Florida, and Georgia. In North Carolina and Alabama, core collecting got under way.

Preliminary computations on core data for Georgia and Florida indicated that specific gravity tends to increase through these States from north to south, and to a lesser extent from west to east. Slash pine varied from 0.477 in central Georgia to 0.660 in southern Florida, and similar trends are apparent for longleaf and loblolly pine. Every overall increase of 0.01 in specific gravity means 50 pounds more dry weight per cord of pulpwood. The specific gravity pattern, as in Mississippi, correlates closely with warm-season rainfall.

In Maine, cooperating industry foresters are collecting the cores, which are processed by the University of Maine, with industry financial help; final data analysis will be done at FPL. The Northeastern



M 121 114

Relation of shortleaf pine density to warm season rainfall distribution in Mississippi.

FPL Technologist Harold E. Wahlgren twists increment borer into Pacific silver fir on Olympic National Forest while associate Dimitri Pronin measures girth of tree, as part of widespread timber quality inventory.

Station, in cooperation with FPL, is working out the important relationship between core density at breast height and average tree density.

In 1960 core collection work was launched in several western States with the cooperation of the Pacific Northwest, Pacific Southwest, and Intermountain Forest Experiment Stations. During 1961, industry began a three-year financial contribution to the western survey. The Douglas Fir Plywood Association, West Coast Lumbermen's Association, and Western Pine Association have agreed to contribute a total of $300,000 to help defray costs of collecting and analyzing some 26,000 cores. Being sampled are the main commercial softwoods, including Douglas-fir, western hemlock, western larch, Pacific silver fir, California red fir, noble fir, grand fir, and white fir. On white fir, special strength studies are accompanying the density work, as described in the section of this report entitled, "Wood Products Engineering Research."

During the 1961 season, a total of 8,964 cores were collected by survey crews on 1,530 sample plots in California, Idaho, Montana, Oregon, Utah, Washington, and Wyoming. Including 4,248 cores received in 1960, a total of more than 6,500 cores from western species were analyzed for specific gravity in the Laboratory.

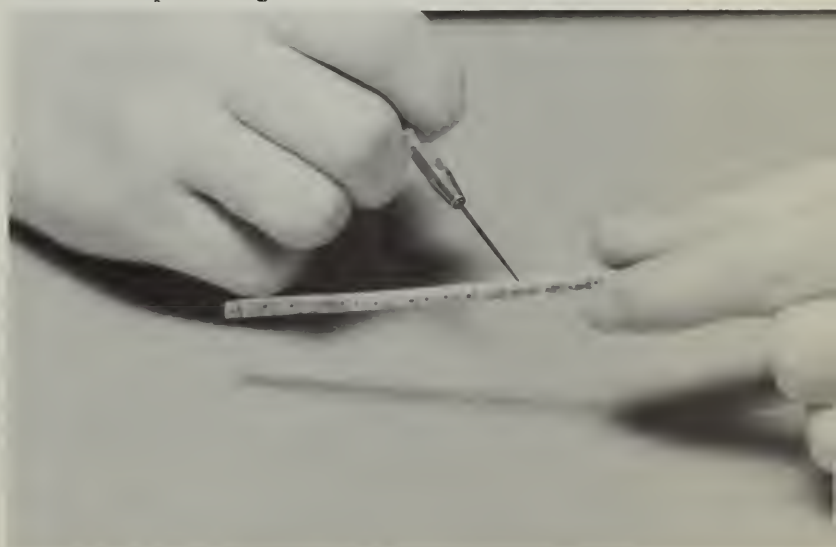
In another phase of the density program, FPL crews during 1961 went into several western States to collect specimens of wood at various heights in trees of the species under study. The purpose of this was to gain an index of specific gravity variation throughout the length of the tree, since past studies have shown that wood higher in a tree is generally less dense than that in the lower part of the stem. These indexes are used to convert specific gravity determinations of increment cores taken at breast height by survey crews to overall tree values.

Through 1961, 1,144 trees of eight western species were indexed in this way, mainly on national forests where timber was being cut by private lumbering concerns that had purchased the stumpage. Trees were sampled in Arizona, California, Colorado, New Mexico, Oregon, and Washington.

Because of the large diameters of many old-growth trees sampled in the West, increment cores were limited to a maximum of 10 inches in length. In the southern pines of the South, all trees had been bored to the pith. Doubts about the reliability of the 10-inch cores have been dispelled by comparisons with the over-all tree gravity determinations made on full-radius samples taken at 20-foot intervals along the tree stem. An essentially straight-line relationship considered as good as any for southern pine was shown in graphs for Douglas-fir and white fir.

Environmental Effects on Quality

How rainfall, sunlight, soil, prevailing winds, and other environmental conditions affect tree growth and wood quality has long been a subject of FPL research. During 1961, for example, published results of a study of loblolly pine growing experiments in Arkansas showed for the first time that soil water availability is closely correlated with such anatomical features as percentage of summerwood in the annual



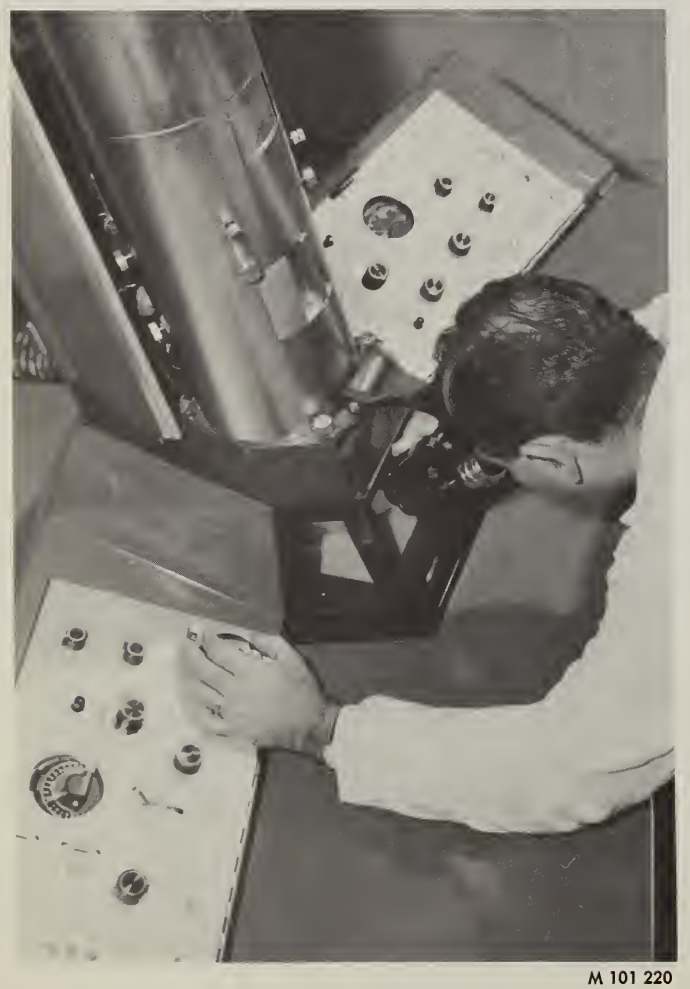
Increment core of southern pine. M 112 350

ring and number and size of summerwood fibers. To get this and other information, trees were dissected and microscopically examined ring by ring from the pith outward to the midpoint of each year's height growth.

A study just beginning is designed to shed light on the effect of wind on the anatomical structure of some softwoods. To get this work under way, instrumentation is being developed and tested that will help record tree reactions to wind.

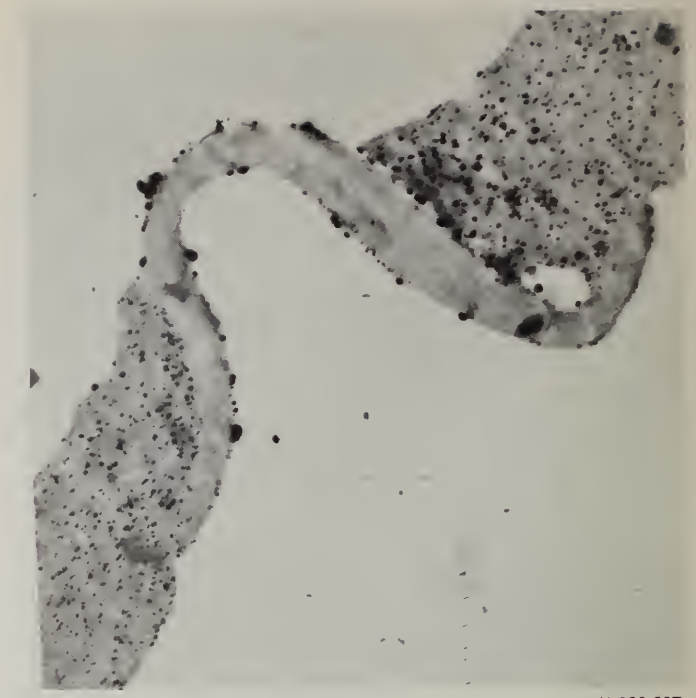
Research done elsewhere has demonstrated that wind stimulates growth activity of the cambium, the layer of growing cells just under the bark that creates a new growth ring each year. It has also been shown that growing cells develop tension stresses along the grain and compression stresses in the circumferential direction. The causes are unknown, but these stresses are so generally present that it can be assumed some common physiological process is stimulated by such a mechanical effect as wind sway.

There is conclusive evidence that the mechanical action of wind stimulates cambial activity. The greatest stresses developed by swaying motion occur near the point of support of the tree, usually at the base, where growth is most rapid. This has been confirmed by experiments in which trees were guyed so that the point of support against wind sway was raised to the height where the guys were attached to the trunk. This became the point of greatest stress and also of greatest diameter growth.



M 101 220

With the electron microscope, Dr. Irving B. Sachs studies wood structure enlarged many thousands of times.



M 120 987

Magnified 32,000 times under electron microscope, lignin shows plainly in pit membrane of loblolly pine from which cellulose has been removed.

Detailed analyses are to be made on wood in the stems of young loblolly pine trees so guyed on the Crossett Experimental Forest in Arkansas by investigators of the Southern Forest Experiment Station. From these analyses it is expected that ideas will be obtained on how the structure and strength of wood may be affected — perhaps improved — by planned exposure of growing trees to wind under controlled silvicultural conditions.

Relation of Structure to Properties

Past research has shed much light on how the structure of wood — including abnormalities such as compression wood and tension wood — affects strength, shrinkage, glue lines in plywood and laminated wood, treatment with preservatives, and bonding together of wood fibers in paper. Current work has centered largely on studies of wood structural details visible for the first time under the electron microscope. Two such investigations under way are aimed at learning more about the nature of the fiber-

to-fiber bond in paper and the distribution of lignin in the cell walls.

The enormous enlargements made possible by the electron microscope, coupled with the radically different operational characteristics of this instrument, comprise in effect an entirely new branch of optical science for which new research techniques are essential. In the study of wood fibers, for example, optical evidence has been obtained for the first time of what not long ago was regarded as the smallest fundamental unit of wood, the crystallite or micell. Heretofore this unit had been encountered only through chemical and x-ray diffraction techniques, by means of which measurements of its size in Angstrom units had been obtained.

Tiny flecks revealed in some electron photomicrographs at enlargements of some 180,000 diameters are assumed to be crystallites because they conform to the measurements obtained by x-ray methods. Much additional work remains to be done to develop techniques for exploring this new lead to greater understanding of such phenomena as fiber-to-fiber bonding in paper.

Similarly, new evidence is being obtained of the presence of lignin throughout the cell walls of wood and in the membrane-like toruses that close the minute openings in cell walls called bordered pits. A strong step ahead in this work was made possible by the finding, discussed in this report under "Wood Chemistry Research," that hydrofluoric acid removes the cellulose from wood sections but leaves the wood structure intact. This technique has made it possible to attain for the first time visual evidence of the presence of substantial amounts of lignin in all three layers of the cell wall and the middle lamella. Heretofore it had been thought that the tertiary, or S_3, layer was virtually pure cellulose. Significance of this finding to new pulping processes seeking to separate the layers of wood cells by differential shrinkage methods is considerable, as pointed out in the section of this report entitled "Wood Fiber Products Research."

Similarly, visual evidence of the presence of lignin in the torus gives chemists firmer ground for planning new methods of chemically attacking these membranes to open up the bordered pits for passage of wood treating liquids and other substances. This work has special application to such difficult-to-treat woods as Douglas-fir.

Identification Service

From King Midas' ancient tomb to a witness chair in a modern murder trial — that's the span of activities encompassed by FPL's free wood identification service during 1961.

Wood specimens from ornate furnishing of a crypt recently opened by archaeologists near Gordion, Turkey, are believed to have come from the tomb of the legendary monarch who wished all he touched would turn to gold — and got his wish.

A crude tree branch allegedly used to club at least one of three women to death in an Illinois State park was sent to FPL for identification and relation to wood splinters taken from the scalp of one of the victims. The request led to witness services in the trial of a man accused of the crime.

Most requests for identification are more routine in character. Nevertheless, they may involve large lumber purchases, legal disputes, or other situations of deep concern to the inquirer. During 1961, the total of such requests showed a substantial increase to 3,044 from the 2,723 received the year before. Some possible economic significance may be attributed to the fact that a new record high in requests for identification services outside the Forest Service preceded the fourth-quarter surge in the Nation's business activity!

Grading Trees and Logs

Development of log and tree grades for important commercial species has potentially high value for all owners of timber, and especially to owners of small acreages. For the most part, Forest Service and other surveys have shown small holdings to be least productive, largely because their owners cannot afford the services of trained foresters. Generally, timber on such holdings is sold on a clear-cutting basis at low unit prices. If reliable tree and log grades were available, such owners could realize much higher returns by selling "on grade" either by selective cutting or clear cutting, depending on stand conditions.

During 1961, FPL contributed considerable technical advice and guidance to the National Log Grade Project under way throughout the Forest Service. Fifteen work plans for studies proposed under this project and 13 manuscripts covering completed work were reviewed for technical content. These included the Forest Service Scaling Manual and the Southern Pine Log Grade Report. Staff members also participated in field work on the white fir, Douglas-fir, ponderosa pine, eastern white pine, and hardwood log-grade studies.

Photographic techniques developed by FPL for log-grade use were used, and various Station personnel were trained in their application.

In related research, FPL published results of an investigation into two methods of measuring lumber volume of hardwood logs, the Scribner Decimal-C log rule and the International ¼-inch log rule. Comparing estimates made with both rules to actual lumber

yields obtained from the logs, it was found that less overrun was obtained on logs measured with the International rule than on those measured with the Scribner rule. It is still necessary, however, to apply an over-run factor to either log rule scale if one is to obtain an accurate estimate of actual lumber yield.

An investigation was begun of the possibilities of applying principles of hardwood lumber grading to low-grade eastern white pine boards. Hardwood lumber is graded on the basis of the yield of cuttings of clear wood from boards with knots and other grade-reducing imperfections. The same principle is being applied to No. 4 Common white pine boards from 4 to 12 inches wide, which have low value as now marketed. Some 500 boards were sampled at each of 10 New England mills. Conclusions await completion of studies comparing estimated with actual yields of clear cuttings.

Informational Activities

FPL has always been operated on the premise that results of its research are of value only as they are made public. Enabling legislation passed by the Congress emphasizes the obligation to distribute research results. This obligation is discharged in several ways: by publication of reports, handbooks, and other printed matter; by correspondence and personal discussion with visitors; and by talks and demonstrations to groups.

Publications

Three broad categories of scientific and technical publications are produced by FPL authors. During 1961 a total of 103 of all categories were published.

For many years FPL has issued a series of research reports now numbering some 2,000. In 1961, a total of 51 new or revised reports were issued. These reports are designed primarily to bring results of research to the attention of scientists, engineers, and others directly interested in detailed presentations of newly completed work within a given limited field of study. Some of these reports, however, are of broader scope.

Paralleling this series of reports is another, called technical notes, some 200 of which are now in existence. These notes are confined to brief descriptions of how to apply some principle of science or research finding to practical problems dealing with the use of wood. One technical note was revised in 1961.

The third category of FPL publications consists predominantly of U.S. Department of Agriculture technical bulletins, agriculture handbooks, home and garden bulletins, and miscellaneous publications; FPL also produces such publications for other agencies of government. Last year two agriculture handbooks, one miscellaneous publication, and one technical bulletin were published. Publications of this category present the substance of broad areas of research findings, generally in terms of their application to major fields of wood use. Thus the Wood Handbook, Agriculture Handbook No. 72, is primarily a guide to better wood use for engineers, architects, and builders.

In 1961 a manual on lumber seasoning prepared by FPL was published by the International Cooperation Administration. And in cooperation with the Department of Defense and the Federal Aviation Agency, FPL produced "Part III: Design Procedures" of Military Handbook 23, "Composite Construction for Flight Vehicles." This document was based in part on research done previously by FPL for the Composite Construction Subcommittee (formerly ANC-23 Panel) of the Federal Aircraft Design Criteria Committee.

Another substantial part of the Laboratory's publication program consists of papers published in scientific, technical, and trade journals. A total of 46 such articles were published during 1961.

The wealth of information available at FPL on wood products is, of course, beneficial to users as well as producers. Such information is occasionally published in mass media of communication, such as newspapers and popular magazines. As time and personnel permit, requests from these media for articles and illustrations are filled. Similar service is provided for radio, television, and motion picture agencies requesting it. A total of 60 news-type articles were prepared during 1961 and distributed to press, radio, and television.

Semiannually a list of new publications is distributed to persons requesting it. Several subject-matter lists of publications are also distributed on request.

Visitors

From 48 States and 48 foreign lands, visitors came to FPL during 1961 for consultation on problems involving research and utilization of wood. They numbered 3,499 of the 10,007 visitors of all types, including tourists, conservationists, homemakers, high school and college students, and industrial and professional groups.

Of the consulting visitors, the largest number by field of interest were those concerned with problems of pulp and paper research and production, who totaled 522. Close behind, at 517, were those interested in gluing, machining, painting and finishing, fireproofing, and other types of solid wood processing. Engineering consultations brought 513, wood preservation matters 293, timber growing, wood structure, sawmilling, machining, and the like 289, packaging 270, and wood chemistry 248. Another 425 consulted FPL information specialists, and 333 conferred with the Director. Library facilities were used by 49, and 40 met with fiscal and administrative officials.

During 1961, 16 major conferences were held at FPL with industry groups. These included the Special Committee on Technical Studies of the National Lumber Manufacturers Association; Committee D-7 on Wood and the subcommittee on pressure tapes of Committee D-10 on Packaging, American Society for Testing and Materials; the Pulp Chemicals Association; the Preservative Standards Advisory Committee of the National Woodwork Manufacturers Association; the Boxboard Research and Development Association; the Technical Committee of the Fibre Box Association; the Chemical Packaging Committee of the Manufacturing Chemists Association; the Techni-

M 119 898

Director Edward G. Locke explains FPL organization to, from left, Nestor Altuve, Director of Natural Resources for Venezuela, and that Nation's Minister of Agriculture, Victor Manual Giminez. Venezuela plans laboratory for wood products research.

cal Review Board of the American Institute for Timber Construction; and a group of door manufacturers.

The Task Group on Basic Stresses of the American Society for Testing and Materials met twice at FPL during the year for conferences on the development of such stresses for lumber.

A meeting to discuss the use of particle board as underlayment for flooring tile involved the National Particleboard Association, the Rubber Manufacturers' Association, and the Asphalt and Vinyl Tile Institute.

FPL research on structural materials for aircraft and rockets was reviewed at a joint meeting of two groups, the ANC-17 Panel on Plastics for Flight Vehicles and the Composite Construction Subcommittee (formerly ANC-23 Panel) of the Federal Aircraft Design Criteria Committee.

Among foreign visitors were five industry groups. Three of these were sponsored by the International Cooperation Administration. These were a Philippine Plywood Industry Productivity Team, a Paper Productivity Team from India, and a Forestry Logging Team from Spain. The other two groups consisted of Japanese foresters and sawmill operators and French corrugated box manufacturers.

Secretary of Agriculture Orville L. Freeman visited FPL November 13, 1961, accompanied by George A. Barnes, Assistant to the Secretary, and Governor Gaylord Nelson of Wisconsin. His visit had been preceded in August by that of Dr. Frank J. Welch, Assistant Secretary of Agriculture in charge of Federal-State relations.

Among other groups visiting FPL were legal officials of 12 States attending the Midwestern Regional Conference of Attorneys General in Madison October 31. FPL's widely known services to law enforcement agencies needing technological assistance in the field of wood and wood products attracted this group.

In July, 67 teachers from 13 Asian and African countries studying in the United States under ICA sponsorship visited FPL on a tour conducted by the National Education Association.

Scientific and Technical Meetings

FPL staff members regularly appear on the programs of major scientific and technical meetings, conventions of trade and industry groups, and government conferences. Some 50 addresses to such organizations were made during 1961. The great majority were national or regional in scope.

Director Edward G. Locke spoke to five groups, among which were the International Union of Forestry Research Organizations in Vienna, Austria, a Governor's Conference on Wood Utilization at Charleston, W. Va., the Mountain States Lumber Dealers Association at Denver, Colo., and the Wisconsin State Chamber of Commerce Natural Resources tour at Trees for Tomorrow Camp, Eagle River.

A staff member attending the Pacific Science Congress in Honolulu, presented two papers, one his own and the other authored jointly by Dr. J. F. Saeman, Chief of the Division of Wood Chemistry, and Dr. Locke.

Among major national organizations before which FPL staff members spoke were the Technical Association of the Pulp and Paper Industry, the American Chemical Society, the Forest Products Research Society, the American Wood-Preservers' Association, the American Pulpwood Association, the Building Research Institute of the National Academy of Sciences — National Research Council, the American Society of Mechanical Engineers, the American Management Association, the American Society of Agricultural Engineers, and the thirtieth annual Shock and Vibration Symposium.

Among regional groups before which technical and scientific papers were given were the Louisiana Forestry Association, the Southern Forestry Congress, the Northeastern Loggers Association, and a quality control short course at Louisiana State University.

Sectional groups of the Forest Products Research Society before which addresses were given were the Carolinas-Chesapeake, Midwest, Northern California, and Northeast sections. The South Atlantic Wood Pole Conference at North Carolina State College, the Eastern Wood Pole Conference at the New York State University College of Forestry at Syracuse Univer-

M 120 995

Chemically stabilized wood gunstocks held attention of (seated, left to right) Secretary of Agriculture Orville L. Freeman, Wisconsin Governor Gaylord Nelson, and George A. Barnes, Assistant to the Secretary. Demonstrating stock is Harold L. Mitchell, chief, division of timber growth and utilization relations; and in background are FPL Director Edward G. Locke, left, and John C. Killebrew, FPL information specialist.

sity, and a University of Wisconsin Wood Pole Institute heard papers presented by FPL staff members.

An FPL housing research engineer addressed a conference on electric house heating and insulation conducted by USDA's Agricultural Research Service in Washington, D.C.

Training

Several demonstrations designed to give up-to-date research results to industry groups were held at FPL during 1961. Longest of these was the 2-week demonstration on kiln drying attended by 25 men, chiefly from industry. This was the 85th such demonstration given in a series begun in 1919. Those enrolled came from the States of Arkansas, Colorado, Georgia, Illinois, Louisiana, Michigan, Mississippi, North Carolina, Pennsylvania, Texas, Vermont, and Wisconsin, and from Canada, China, Colombia, and Mexico.

A 1-week training conference was conducted for the Southern Pine Association, with 21 in attendance from Georgia, Texas, Louisiana, Arkansas, and Washington, D.C. Subject matter ranged from growth-quality relationships and basic strength properties of southern pine to structural design, seasoning, gluing and laminating, wood finishing, and fireproofing and preservative treatments.

Twenty-five field staff members of the National Lumber Manufacturers Association attended a 1-day training demonstration. A similar program was arranged for the Northern Illinois Home Builders Association.

Small-sawmill specialists conducted five clinics for operators, two in Washington, two in Oregon, and one in Michigan. These were attended by operators of such mills. This type of training is aimed at making mills more efficient by showing how logs can be cut into higher grade lumber with less waste from faulty and off-size cutting.

One sawmill specialist participated in a western hardwood utilization symposium at Berkeley, Calif., and another gave on-the-ground assistance to the Chippewa-Cree Indian tribe just starting a small sawmill enterprise in Montana.

Student Programs

As is true in any specialized field, forest products research requires highly trained scientists and engineers. A college degree is but a gate pass. How well the young graduate adapts his educational equipment to the new tasks he undertakes once inside the laboratory depends to a considerable extent upon the on-the-job training he receives. At FPL this type of training has long been given to new employees.

In recent years, two programs have been launched which in effect provide training in laboratory skills and procedures to young men and women still attending classroom lectures. One of these is a program for graduate students enrolled at the University of Wisconsin for advanced study, and the other is a summer-work program for undergraduates interested in forest products research.

In 1961, under a cooperative program with the University of Wisconsin, research employment was given to 14 graduate students. These students came from undergraduate schools in widely scattered parts of the Nation, having been attracted by the combination of a famous graduate institution and FPL's research opportunity. Seven of these were engaged in engineering research as part of their graduate studies, and one each in research on the pulping of wood, structural characteristics of wood, fire protection, wood-water relations, termite investigations, wood-decaying fungi, and bacterial infections in wood.

The research these students were engaged in will generally be presented in dissertations for master's or Ph. D. degrees and FPL publications.

During 1961 a summer training program was conducted for 21 undergraduate students. Six worked on

Eighteen of the 21 undergraduate college students, from sophomore to senior in standing, who participated in FPL 1961 on-the-job training in research.

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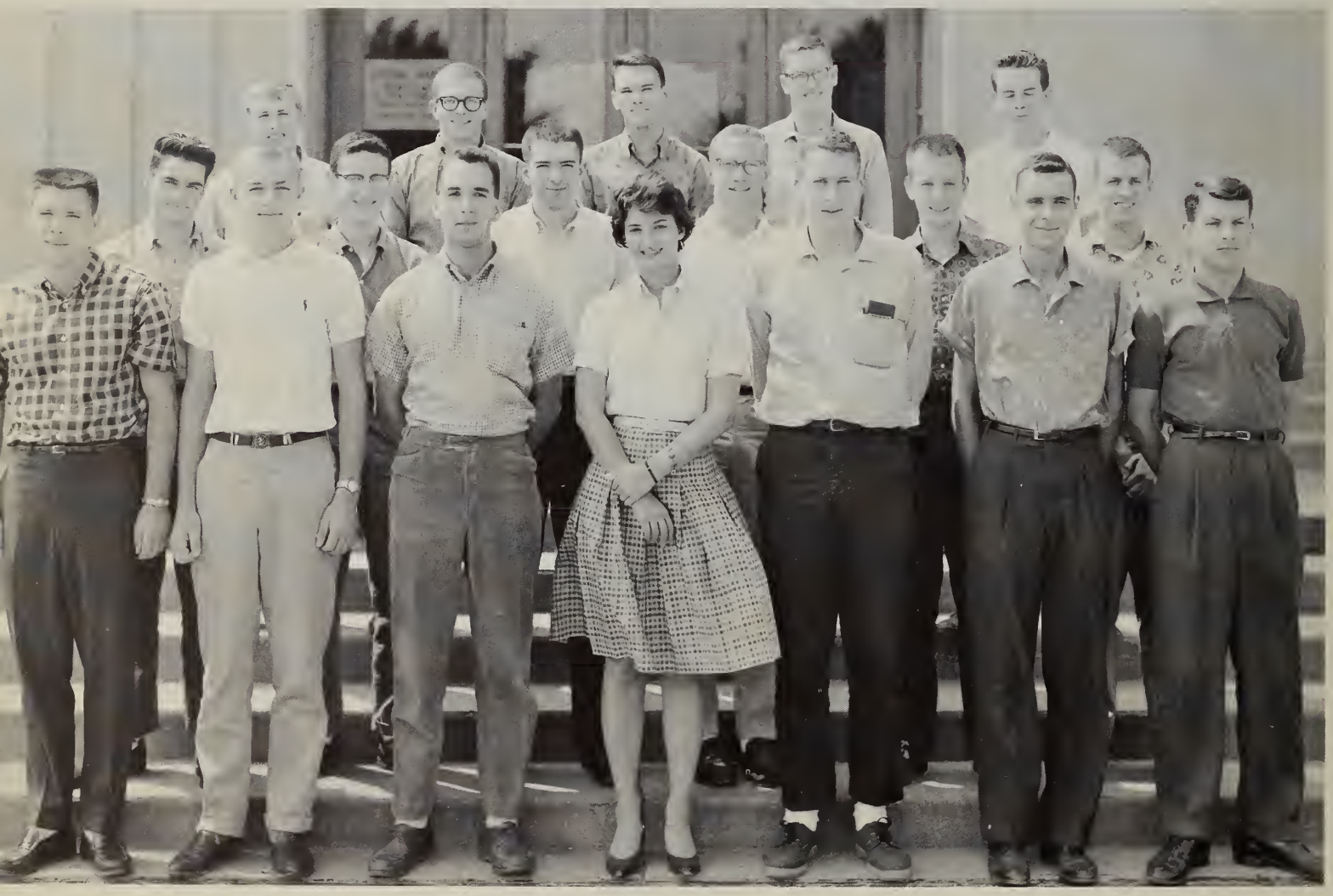

timber processing assignments, five in pulp and paper research, three in wood chemistry, two in engineering research, two in wood structure-properties relations, one in packaging research, one in technical photography, and one in statistics.

One object of this work is to give young students an opportunity to test their talents on actual research jobs.

Students from 13 universities and colleges were employed last year. They came from Syracuse, Michigan State, Illinois, Iowa State, Michigan, New Hampshire, Wisconsin, Cornell, St. John's (Collegeville, Minn.) and North Carolina Universities, and from Oberlin (Ohio) College, Rochester (N.Y.) Institute of Technology, and Augustana (Illinois) College.

Last year only one of every four students who applied could be selected for the small number of summer jobs available. Acceptance was based on above-average academic records and recommendation of the students' faculty adviser. Students hired ranged from sophomore to senior in academic standing.

In time, it is hoped to build a reservoir of young men and women skilled in forest products research and better qualified to take on research jobs at FPL and other research institutions. The need is great and varied; and as progress continues, the demand for research workers experienced in increasingly complex specialties grows apace. On-the-job training during the college years provides that experience at a time when it is most useful both to the student and to prospective full-time employers.

With that goal foremost, FPL hopes to continue and expand both its graduate and undergraduate programs of part-time research.

Under a new program launched in 1961, contracts were concluded with five universities for graduate research projects. A student at the University of California will appraise and evaluate ponderosa pine stumpwood as a source of wood rosin. At the University of Idaho, a graduate student will study the growth-quality relations affecting physical, mechanical, and chemical properties of western redcedar. Forces and temperatures affecting wood cutting operations will be investigated by a University of Michigan graduate student, while at the University of Minnesota the factors underlying initial infection of wood by decay fungi will be looked into. Studies on the catalytic hydrogenation of lignin during pulping processes will be done at the New York State College of Forestry at Syracuse University. Other contracts are pending with Colorado State University, Oregon State University, and the University of Wisconsin under this program.

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